United States Patent [19]

Stenlund

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[54] **HEAT EXCHANGER**

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[52] U.S. Cl. **165/119**; 165/51; 165/154; 165/916; 123/41.33; 184/104.1; 184/104.3; 210/184; 210/186

[58] Field of Search .... 165/103, 51, 119, 154, 165/916; 123/41.33, 196 AB; 184/6.22, 104.3; 210/184, 186

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Primary Examiner—John Ford

Attorney, Agent, or Firm—Browdy and Neimark

[57] **ABSTRACT**

A heat exchanger for exchange of heat between two liquid media, particularly an oil-water-heat exchanger for cooling engine or transmission oil in an automotive vehicle with the aid of the cooling water flow of the engine, comprises two heat-exchange chambers (1, 2) mutually separated by a common liquid-impervious partition wall (3) and intended to be through-passed by a respective one of the media. The partition wall (3) is tubular with a circular cross-section and open axial ends forming an inlet and an outlet for the water. The heat-exchange chamber (1) for the water is annular and located radially inwards of the partition wall and encloses a direct flow path for the water from the inlet (4) to the outlet (5), and communicates with the direct flow path in a manner such that only part of the total water flow through the inlet (4) will pass through the said heat-exchange chamber (1), whereas the remainder of the water will flow along the direct flow path to the outlet (5). The other heat-exchange chamber (2) intended for the oil is annular and encircles the outer surface of the tubular partition wall (3).

7 Claims, 1 Drawing Sheet

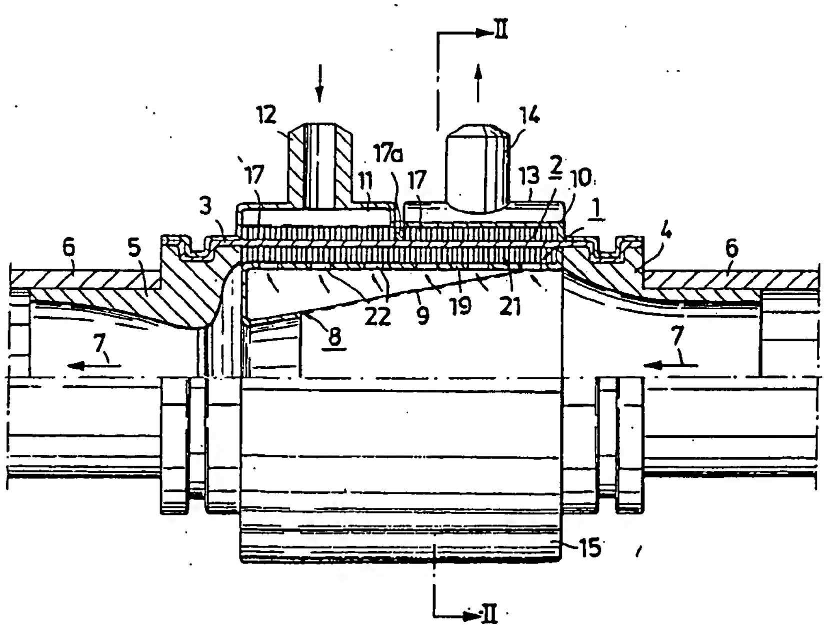

Fig. 1

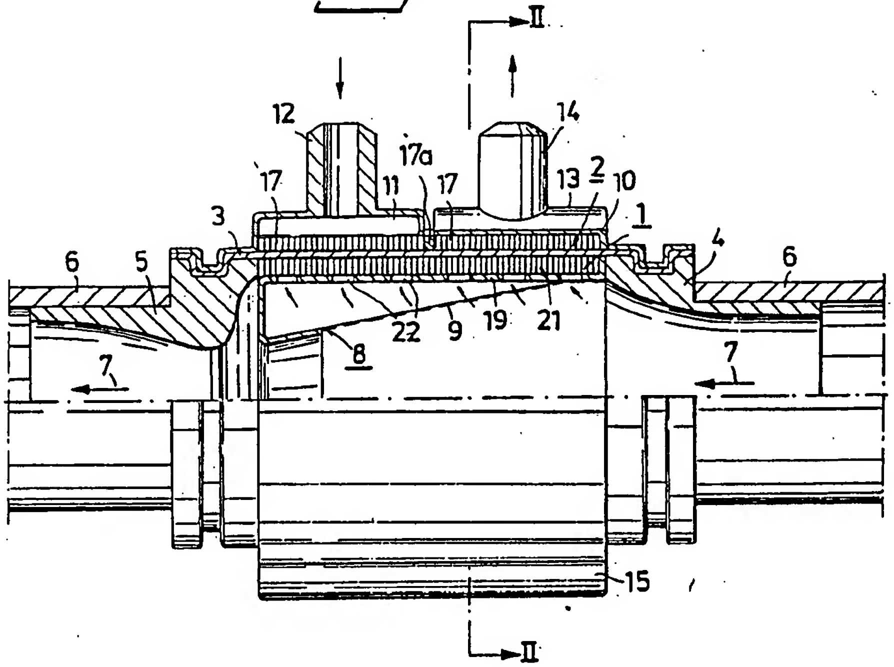
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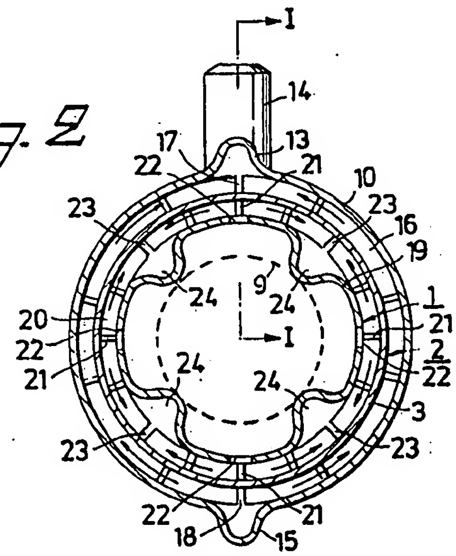
Fig. 2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HEAT EXCHANGER

BACKGROUND

The present invention relates to a heat exchanger intended for effecting an exchange of heat between two liquid media and comprising two heat-exchange chambers which are separated from one another in a liquid-tight fashion by means of a common liquid-impervious partition wall, and each of which is intended to be through-passed by a respective one of such two liquid media.

The heat exchanger according to this invention was developed primarily for use in automotive vehicles for cooling lubricating oil or hydraulic oil with the aid of the engine cooling water as the cooling medium.

The internal combustion engine of automotive vehicles is cooled primarily with water, or commonly with a mixture of water and glycol, which in turn is cooled in an air-water-cooler. In order not to subject the engine to excessive thermal stresses, the temperature of the water coolant is changed only to an insignificant extent during its passage through the air-water-cooler. Consequently, it is necessary to use a very large volumetric flow of cooling water in order to achieve the requisite engine cooling effect. In the case of modern engines, there is also a need to cool the engine oil, and in many cases also the oil in the vehicle transmission system. This can be achieved with the aid of air or by using the engine-cooling water as a coolant. Earlier it was quite usual to cool the oil by means of an air-cooler, but this method has become progressively less usual, since the coolers involved are bulky and a large number of coolers are required, which makes it difficult to utilize the cooling air-flow effectively. Consequently, it has become more usual to cool the oil with the engine cooling water as the coolant. In principle this can be effected in two different ways. The first of these methods involves the embodiment of a water-oil-cooler in the collecting box of the engine air-water-cooler. This arrangement is often used for cooling the oil in automatic gear boxes. In this case, the oil is led to the engine air-water-cooler through hoses. The second of the aforesaid methods involves passing the flow of engine cooling water, or a part thereof, to a water-oil-cooler which is placed close to the component whose oil is to be cooled. Thus, in this case it is water which is passed through hoses to the oil-water-cooler. One example of this particular arrangement is found in the engine oil coolers which are fitted between the engine block and the oil filter. Only a part of the total flow of engine cooling water is passed through these oil coolers. Since according to the first of the aforesaid methods, an oil cooler is placed in the collecting box of the engine air-water-cooler, it is difficult to avoid disturbing the function of the air-water-cooler, which is of prime importance for cooling the engine, or to avoid impairing the oil cooling conditions. Since according to the second of the aforesaid methods the oil-water-coolers are placed in the close vicinity of the components whose oil is to be cooled, a large amount of space is required to accommodate the oil-water-coolers of present day construction and a comprehensive and complicated network of pipes and hoses is required to conduct the cooling water to the coolers. Furthermore, conventional oil-water-coolers require a troublesome high pressure drop for the flow of cooling water, which is a drawback in engine-cooling-water systems.

SUMMARY

Consequently, an object of the present invention is to provide firstly a heat exchanger which can be used with particular advantage for cooling the engine oil and transmission oil of automotive vehicles with the aid of the flow of engine cooling water; secondly a heat exchanger which can be given a small total volume and, despite this, a high heat-exchange efficiency; and thirdly a heat exchanger which can be placed at any suitable, desired location in the cooling water circuit of the engine with only a very slight increase in the pressure drop in the cooling water flow as a result thereof.

The primary characteristic features of a heat exchanger constructed in accordance with the invention are set forth in the following claims.

When the inventive heat exchanger is used as an oil cooler in an automotive vehicle, a very large flow of cooling water, e.g. all of the engine cooling water, may be passed straight through the heat exchanger, with only very small flow losses and only a very slight drop in pressure, wherewith only that part of the flow of cooling water needed for the heat-exchange requirement in question is passed through the heat-exchange chamber located inwardly of the tubular partition wall, while the oil flows through the heat-exchange chamber which is located outwardly of the tubular partition wall. Such an oil cooler can be fitted in a hose intended for conducting cooling water. If desired, the cooler can be given an external diameter which is only slightly larger than the external diameter of the hose. An oil cooler which is constructed in accordance with the invention can also be integrated with or embodied in the engine at a location in which the cooling water flows. This obviates the need for auxiliary external conduits, in the form of pipes or hoses. When cooling transmission oil and the engine and transmission are integrated to form a rigid unit or assembly, the conduits required may consist of rigid pipes, therewith eliminating the need for flexible hoses.

Both of the heat-exchange chambers of the inventive heat exchanger may be configured for turbulent flow of the medium flowing through said chambers, in accordance with present day standard heat-exchange principles. However, a particular advantage is afforded when one or both of the heat-exchange chambers of an inventive heat exchanger is or are configured to engender laminar flow of the through-passing medium, and to work in accordance with the heat-exchange principle described in International Patent Application PCT/SE 84/00245, corresponding to U.S. Ser. No. 06/847,659. This heat-exchange principle affords a very high heat-exchange effect per unit of volume of the heat exchanger. This can also be achieved with a relatively small volumetric flow and also with a low pressure-drop of the through-flowing medium.

When using a heat exchanger constructed in accordance with the invention as a water-oil-cooler, the oil flowing through the outer chamber of the heat exchanger has unfavourable heat exchange characteristics and the volumetric flow of said oil is normally comparatively small. Consequently, it is particularly beneficial in this case to configure the outer heat-exchange chamber for laminar flow of the oil and in accordance with the heat-exchange principle taught in the aforementioned international patent application. The volumetric

flow of oil in, e.g., internal combustion engines is contingent on the engine lubricating requirements and is relatively small, so that conventional heat-transfer functions which work with turbulent flow would result in an inventive heat exchanger of impracticable large volume. In the case of automatic gear boxes, the requisite volumetric oil flow is governed by the requirements of the transmission system and is, in this case, so small as to result in an inventive heat exchanger of impracticably large dimensions when the heat exchanger is constructed for turbulent oil flow. Since the cooling requirement lies close to the maximum requirement possible with regard to the volumetric oil flow, it is obvious that the best possible heat exchange principle should be used. The engine cooling water used to cool the oil has very favourable heat-transfer properties and is also present in large quantities, and consequently there can be used in the inwardly located heat-exchange chamber of the inventive heat exchanger either a conventional heat-exchange principle with turbulent flow, or the aforementioned heat-exchange principles with laminar flow, in accordance with the aforementioned patent application. The conventional heat-exchange principle with turbulent flow requires a greater volumetric flow through the inner heat-exchange chamber, i.e. that a greater part of the total cooling water flow is conducted through the inner chamber, and therewith requires an inner chamber of greater volume while, at the same time, requiring a greater pressure drop across the inner chamber. The flow areas of such a heat-exchange chamber, however, will be relatively large and the risk of blockages occurring will thus be relatively small. On the other hand, the heat-exchange principle which employs laminar flow requires a significantly smaller volumetric flow through the inner heat-exchange chamber, resulting in a chamber of smaller volume and also a lower pressure drop across the same. The through-flow areas of such a chamber are smaller, however, and the risk of blockages occurring therein are consequently greater, therewith heightening the need to use clean cooling water.

BRIEF DESCRIPTION OF DRAWING

The invention will now be described in more detail with reference to the accompanying schematic drawing, which illustrates by way of example an advantageous embodiment of the inventive heat exchanger and in which

FIG. 1 is a side view, partly in axial section, of a heat exchanger constructed in accordance with the invention; and

FIG. 2 is a radial sectional view of the heat exchanger of FIG. 1.

The illustrated inventive heat exchanger is configured, e.g., for cooling transmission oil in automotive vehicles with the use of the engine cooling water of the vehicle as the cooling medium.

DETAILED DESCRIPTION

The illustrated heat exchanger includes an inner, annular heat-exchange chamber, generally referenced **1**, through which cooling water is intended to pass, and an outer, annular chamber, generally referenced **2**, through which the oil is intended to pass, these chambers being separated from one another by a cylindrical, tubular liquid-impervious partition wall **3**. The tubular partition wall **3** has fitted to respective ends thereof an inlet connector **4** and an outlet connector **5** by means of which a hose **6** which conducts engine cooling water can be connected to the heat exchanger. Thus, all of the cooling water will pass through the heat exchanger, as indicated by the arrow **7**, wherewith only that part of the total cooling water flow which is required for heat exchange purposes is conducted through the inner chamber **1** in heat exchange contact with the partition wall **3**, whereas the remaining part of the cooling water flow flows past the inner chamber **1**, radially inwards thereof, without taking any appreciable part in the heat exchange process. This division of the cooling water is achieved as a result of the special configuration of the direct flow path of the cooling water radially inwards of the heat-exchange chamber **1**, i.e. the path leading straight from the inlet connector **4** to the outlet connector **5**. This direct flow path or channel is configured so as to engender a zone of relatively high pressure in which the inlet to the inner chamber **1** is located, and so as to engender a zone of relatively low pressure in which the outlet from the inner chamber is located. These zones can be generated in various different ways. For example, there may be provided in the direct flow channel for cooling water, a rigid or flexible throttle means, or alternatively, and even preferably, a variable, elastic throttle means which will conform to the volumetric flow of the cooling water, such as to create upstream of the throttle means a zone of relatively high pressure in which the inlet to the inner chamber **1** can be located, and such as to create downstream of the throttle means a zone of relatively low pressure in which the outlet from the inner chamber **1** can be located.

In the case of the illustrated, preferred embodiment, the desired zones of mutually different pressures are created by configuring the inlet connector **4** to form a diffuser which has a gradually increasing flow area, so that the flow rate will fall and the static pressure increase. Furthermore, there is arranged coaxially inwards of the inner heat-exchange chamber **1** a cylindrical wall, generally referenced **8**, which tapers conically towards the outlet and which partially comprises a screen device or filter wall **9** which functions as an inlet to the inner chamber **1**, as described in more detail hereinafter. The cylindrical conically, tapering wall **8** forms an ejector which increases the velocity of the liquid flow and lowers the static pressure, the outlet from the inner chamber being located at the downstream end of said wall, as described in more detail hereinafter. The outlet connector **5** also has the form of a diffuser which has a gradually increasing area in the flow direction, such as to recover as much as possible of the kinetic energy generated in the ejector, so that the total pressure drop of the flow of the cooling water through the heat exchanger will be low.

The inner heat-exchange chamber **1** and the outer heat-exchange chamber **2** of the illustrated, advantageous embodiment of an inventive heat exchanger are both configured for laminar flow of the flowing medium, in accordance with the heat-exchange principle described in the aforementioned international patent application.

The outer chamber **2**, through which the oil flows, lies between the tubular partition wall **3** and the sleeve-like outer wall **10** which extends co-axially with and around the partition wall **3** at a radial distance therefrom, and the axial ends of which are connected to the outer surface of the partition wall in a liquid-tight manner. The cylindrical outer wall **10** has formed therein an

axially extending inlet chamber 11, which is provided with an oil-inlet pipe stub 12 and which extends along half the axial length of the chamber 2, and also an axially extending outlet chamber 13 which extends in line with the inlet chamber 11 and is provided with an oil-outlet pipe stub 14 and extends along the remaining half of the heat-exchange chamber 2. At a location diametrically opposite the inlet chamber 11 and the outlet chamber 13, the cylindrical outer wall 10 has formed therein an axially extending connecting chamber 15 which extends along the whole length of the heat-exchange chamber 2. Formed integrally with the outer surface of the partition wall 3 are a large number of peripherally extending fins 16 which define therebetween peripherally extending, slot-like flow channels in which the oil can flow in laminar fashion. The fins 16 are broken at a location opposite the inlet chamber 11 and the outlet chamber 13 by an axially extending channel 17, which is divided into two halves by a transverse wall 17a, of which halves one is located radially inwards of the inlet chamber 11 and the other radially inwards of the outlet chamber 13. The fins 16 are also broken in a similar manner at a location opposite the connecting channel 15, by an axially extending channel 18 which extends unbroken along the entire axial length of the heat-exchange chamber 2. The oil thus flows in through the inlet 12 and into the inlet chamber 11, and from there to the left-hand part of the channel 17 as seen in FIG. 1. The oil leaves the channel 17 and disperses through the peripherally extending slot-like flow channels between the fins 16, in which the oil flows in laminar flow in a peripheral direction to the axially extending channel 18 and the connecting channel 15. The oil flows in a turbulent fashion in the connecting channel 15 and into the right-hand part of the heat-exchanger as seen in FIG. 1, where the oil again disperses from the axial channel 18 and into the peripherally extending, slot-like flow channels between the fins 16, in which the oil flows peripherally in a laminar fashion, as shown by arrows in FIG. 2, up to the right-hand half of the axial chamber 17, as seen in FIG. 1, and the outlet chamber 13 located externally of said channel 1. The oil then leaves the heat exchanger through the outlet 14. The outer heat-exchange chamber 2 is thus divided into two halves which are connected in series and each of which is through-passed by oil in sequence, which from the aspect of heat exchange affords a more favourable temperature difference between the oil and the cooling water flowing through the inner heat-exchange chamber 1.

The inner heat-exchange chamber 1 is defined by the tubular partition wall 3 and a substantially cylindrical plate 19 which extends co-axially with and radially inwards of the partition wall 3, one axial end of the cylindrical plate 19 being bent or curved to form the narrowest part of the aforementioned ejector surface 8. The inner surface of the partition wall 3 is also provided with peripherally extending fins, here referenced 20, which are integral with said surface and which define therebetween slot-like flow channels, in which the cooling water flows in laminar fashion. The fins 20 are broken by four axially extending channels 21 which are distributed uniformly around the periphery and into which the cooling water flows via the conical screen structure 9 and apertures 22 provided in the plate 19, as indicated by arrows in FIG. 1. The cooling water flows from the axially extending channels 21 into the peripherally extending, slot-like flow channels between respective fins 20, and flows peripherally in said channels, as indicated by arrows in FIG. 2, and into channels 23 which interrupt the axially extending fins 20. At a location inwardly of the channels 23 the cylindrical plate 19 presents inwardly curved, axially extending channels 24, here referred to as troughs, the flow area of which increases progressively in a direction towards the outlet connector 5 and in which the cooling water, subsequent to passing through the heat-exchanger chamber 1, is collected and conducted to the open ends of the troughs 24 downstream of the aforementioned ejector. As previously described, part of the total flow of cooling water is passed through the chamber 1 under the influence of the difference in the pressures prevailing upstream and downstream of the ejector.

The filter or screen structure 9, which forms part of the ejector, is supported against the inwardly facing apeces of the troughs formed in the cylindrical plate 19 and forming the channels 24. The inflow of cooling water to the heat-exchange chamber 1 through the screen 9 thus takes place in a direction which is substantially perpendicular to the direct flow path of the cooling water from the inlet connector 4 to the outlet connector 5. An advantage is afforded when the through-flow area of the filter or screen 9 is such that the flow rate of the water therethrough is much lower than the rate of flow of the water along the surface of said filter or screen and so that a low pressure drop is obtained across the filter in relation to the pressure drop across the inner heat-exchange chamber 1 and also in relation to the dynamic pressure in the direct flow path of cooling water from the inlet connector 4 to the outlet connector 5. When these conditions are fulfilled, particles and contaminants which may be liable to block the flow channels in the inner chamber 1 will not pass through the filter 9, and neither will particles be able to fasten to the inner surface of the filter and clog the same. Instead, these particles and other contaminants are flushed away, along the filter 9. It will be understood that the filter 9 may be replaced with some other surface which is perforated to allow the passage of the cooling water.

As illustrated in FIG. 2, the fins 16 in the outer heat-exchange chamber 2 and the fins 20 in the inner heat-exchange chamber 1 are broken by means of a plurality of narrow, axially extending slots, the function of which is described in detail in the aforementioned international patent specification.

Although in the aforegoing there has been described primarily a heat exchanger which is constructed as a water-oil-cooler for cooling engine oil and transmission oil in automotive vehicles, it will be understood that a heat exchanger constructed in accordance with the invention can be used advantageously for many other purposes.

I claim:

1. A heat exchanger for effecting an exchange of heat between two liquid media and comprising means forming two heat-exchange chambers which are separated from one another in a liquid-tight fashion by means of a common liquid-impervious partition wall, and each of which is intended to be through-passed by a respective one of said media, characterized in that the partition wall is essentially tubular and has a substantially circular cross-section and open, axial ends which form an inlet and an outlet respectively for said one medium; in that the one heat-exchange chamber for said one medium is annular in shape and is located on the radially inward side of the tubular partition wall and encloses a direct flow path for said one medium from the inlet to

the outlet at mutually opposite ends of the partition wall, and communicates with said direct flow path in a manner such that solely a part of the medium flowing in through said inlet passes through said one heat-exchange chamber while the remainder of said flow passes along said direct flow path to the outlet without passing through said one-heat exchange chamber; and in that the other heat-exchange chamber intended for the other of said media is annular in shape and extends around the outer surface of the tubular partition wall; wherein the partition wall is provided on its inner surface with a large number of peripherally extending fins which define therebetween peripherally extending, slot-like flow channels for said one medium; in that the fins are broken by a plurality of axially extending slots which are uniformly distributed around the periphery and which function alternately as distribution channels and collecting channels for said first medium to and from said peripherally extending flow channels respectively; in that the distribution channels communicate with said direct flow path through openings provided in a cylindrical sleeve which is located inwardly of said fins and which abuts the radially inward edges of the fins; and in that the collecting channels communicate with said direct flow path through axially extending, inwardly curved channels or troughs which are open in the downstream direction and which are formed in said cylindrical sleeve.

2. A heat exchanger for effecting exchange of heat between a first liquid medium and a second liquid medium, comprising a tubular structure with a substantially circular cross-section, a liquid impervious wall and open axial ends forming an inlet and an outlet respectively for said first medium and forming a continuous and permanently open flow path for a main flow of said first medium from said inlet end to said outlet end; a first heat-exchange chamber with an annular substantially circular cross-section coaxially encircling said main flow path of said tubular structure; and a second heat-exchange chamber with an annular substantially circular cross-section encircling coaxially said first heat-exchange chamber; said first and second heat-exchange chambers being separated from one another in a liquid-tight fashion by a common liquid-impervious partition wall forming part of the liquid-impervious wall of said tubular structure; said second heat-exchange chamber having an inlet and an outlet for a flow of said second medium; said first heat-exchange chamber having at least one inlet opening and at least one outlet opening communicating with said main flow path of said tubular structure with the inlet opening located upstream of the outlet opening with respect to the flow in said main flow path; and said main flow path of said tubular structure having means creating at said inlet opening of said first heat-exchange chamber a local static pressure which is higher than the static pressure at the axial inlet end of said tubular structure and means creating at said outlet opening of said first heat-exchange chamber a local static pressure which is lower than the static pressure at the axial outlet end of said tubular structure so that the pressure difference between said inlet opening and said outlet opening of said first heat-exchange chamber is larger than the pressure difference between the axial inlet end and the axial outlet end of said tubular structure and so that a part of said main flow is diverted to flow through said first heat-exchange chamber via said inlet and outlet openings thereof; said main flow path of said tubular structure having a substantially circular cross-section with a diameter which increases gradually from said axial inlet end to a location at said inlet opening of said first heat-exchange chamber, decreases gradually from a location at said inlet opening of said first heat-exchange chamber to a location at said outlet opening of said first heat-exchange chamber, and increases gradually from a location at said outlet opening of said first heat-exchange chamber to said axial outlet end of said tubular structure; the part of said main flow path having a gradually decreasing diameter being defined by a substantially frustoconical surface, said surface having over a part of its length closest to its wider end a plurality of inlet openings to said first heat-exchange chamber.

3. A heat exchanger as claimed in claim 2, wherein said part of said frustoconical surface having said plurality of inlet openings has the form of a screening surface.

4. A heat exchange for effecting exchanger of heat between a first liquid medium and a second liquid medium, comprising a tubular structure with a substantially circular cross-section, a liquid impervious wall and open axial ends forming an inlet and an outlet respectively for said first medium and forming a continuous and permanently open flow path for a main flow of said first medium form said inlet end to said outlet end; a first heat-exchange chamber with an annular substantially circular cross-section coaxially encircling said main flow path of said tubular structure; and a second heat-exchange chamber with an annular substantially circular cross-section encircling coaxially said first heat-exchange chamber; said first and second heat-exchange chambers being separated from one another in a liquid-tight fashion by a common liquid-impervious partition wall forming part of the liquid-impervious wall of said tubular structure; said second heat-exchange chamber having an inlet and an outlet for a flow of said second medium; said first heat-exchange chamber having at least one inlet opening and at least one outlet opening communicating with said main flow path of said tubular structure with the inlet opening located upstream of the outlet opening with respect to the flow in said main flow path; and said main flow path of said tubular structure having means creating at said inlet opening of said first heat-exchange chamber a local static pressure which is higher than the static pressure at the axial inlet end of said tubular structure and means creating at said outlet opening of said first heat-exchange chamber a local static pressure which is lower than the static pressure at the axial outlet end of said tubular structure so that the pressure difference between said inlet opening and said outlet opening of said first heat-exchange chamber is larger than the pressure difference between the axial inlet end and the axial outlet end of said tubular structure and so that a part of said main flow is diverted to flow through said first heat-exchange chamber via said inlet and outlet openings thereof.

5. A heat exchanger as claimed in claim 4, wherein said main flow path of said tubular structure has a substantially circular cross-section with a diameter which increases gradually from said axial inlet end to a location at said inlet opening of said first heat-exchange chamber, decreases gradually from a location at said inlet opening of said first heat-exchange chamber to a location at said outlet opening of said first heat-exchange chamber, and increases gradually from a location at said outlet opening of said first heat-exchange

chamber to said axial outlet end of said tubular structure.

6. A heat exchanger as claimed in claim 4, wherein said partition wall is provided on its inner surface with a large number of peripherally extending fins defining therebetween peripherally extending, slot-like flow channels for said first medium, said fins being broken by a plurality of axially extending interruptions uniformly distributed around the periphery and forming alternately axially extending distribution channels and collecting channels for said first medium to and from said peripherally extending flow channels respectively, said distribution channels communicating with said main flow path through inlet openings provided in a substantially cylindrical sleeve located inwardly of said fins and abutting the radial inward edges of said fins; and said collecting channels communicating with said main flow path through axially extending, inwardly curved troughs which are formed in said sleeve and are open in the downstream direction.

7. A heat exchanger as claimed in claim 4, wherein said partition wall is provided on its outer surface with a large number of peripherally extending fins defining therebetween peripherally extending slot-like flow channels for said second medium, said fins being encircled by a substantially cylindrical sleeve abutting the radially outward edges of said fins and configured to present two axially extending and sequentially arranged chambers, each of which extends over a respective half of the axial length of said partition wall and which are provided with said inlet and said outlet for said second medium, and a third chamber extending axially along the total axial length of said partition wall diametrically opposite said first and second chambers.

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United States Patent [19]

Kadotani

[11] **Patent Number: 6,157,778**

[45] **Date of Patent: Dec. 5, 2000**

[54] **MULTI-TEMPERATURE CONTROL SYSTEM AND FLUID TEMPERATURE CONTROL DEVICE APPLICABLE TO THE SAME SYSTEM**

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[73] Assignee: **Komatsu Ltd.**, Tokyo, Japan

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Jun. 20, 1996	[JP]	Japan	8-180102
Jun. 20, 1996	[JP]	Japan	8-180103

[51] **Int. Cl.**[7] **F24H 1/10**

[52] **U.S. Cl.** **392/483**; 392/495; 165/154

[58] **Field of Search** 392/483, 487–91, 392/495; 165/154, 159, 160, 164, 177, 179, 183

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7-280470	10/1995	Japan	F28D 7/14
8-10676	1/1996	Japan	H01L 21/205
8-181082	7/1996	Japan	H01L 21/22

Primary Examiner—Mark Paschall
Assistant Examiner—Thor Campbell
Attorney, Agent, or Firm—Koda & Androlia

[57] **ABSTRACT**

A fluid temperature control device is improved to be simpler in structure, less in fluid temperature non-uniformity, and able to heat a fluid having a small light absorbability. The fluid temperature control device has a cylindrical inner vessel (**20**), a cylindrical outer vessel (**22**) surrounding the inner vessel (**20**), and a heating lamp (**25**) inserted into the inner vessel (**20**). Metal fins (**28*a***) and (**28*b***) are provided on the inner and outer circumferential surfaces of the inner vessel (**20**). A working fluid is passed through the inner space (**21**) between the inner vessel (**20**) and the heating lamp (**25**), and a cooling liquid is passed through the outer space (**23**) between the inner vessel (**20**) and the outer vessel (**22**). Infrared rays from the heating lamp (**25**) heat the working fluid, and the cooling liquid cools the working fluid. This device is applicable to, for instance, temperature control of plural process chambers of semiconductor processing apparatus. A plurality of the temperature control devices are arranged in the vicinity of the semiconductor processing apparatus. Each of the devices is assigned to each of plural portions of the process chambers and provides the temperature-controlled fluid exclusively to each portion.

23 Claims, 13 Drawing Sheets

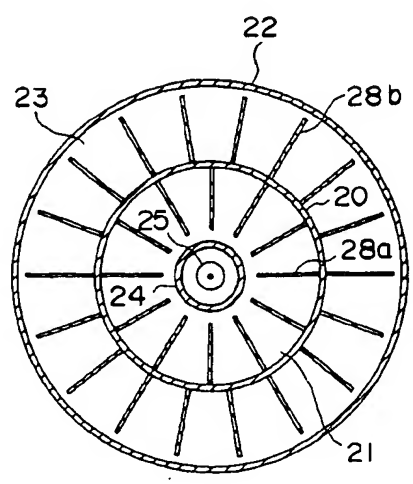


FIG. 1
PRIOR ART

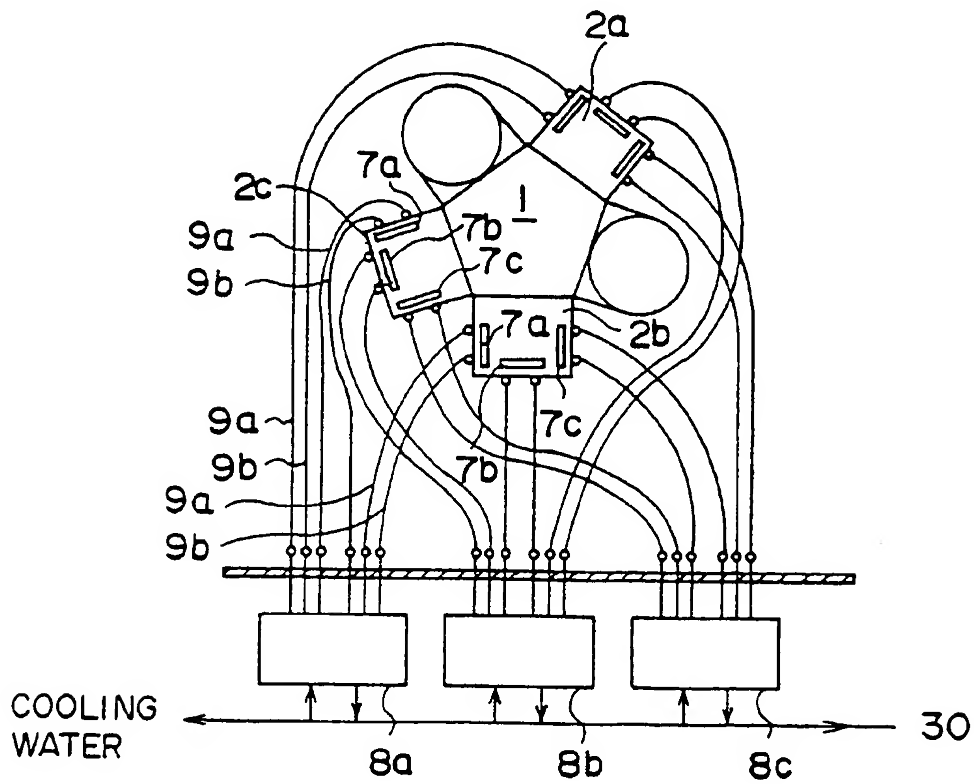


FIG. 2
PRIOR ART

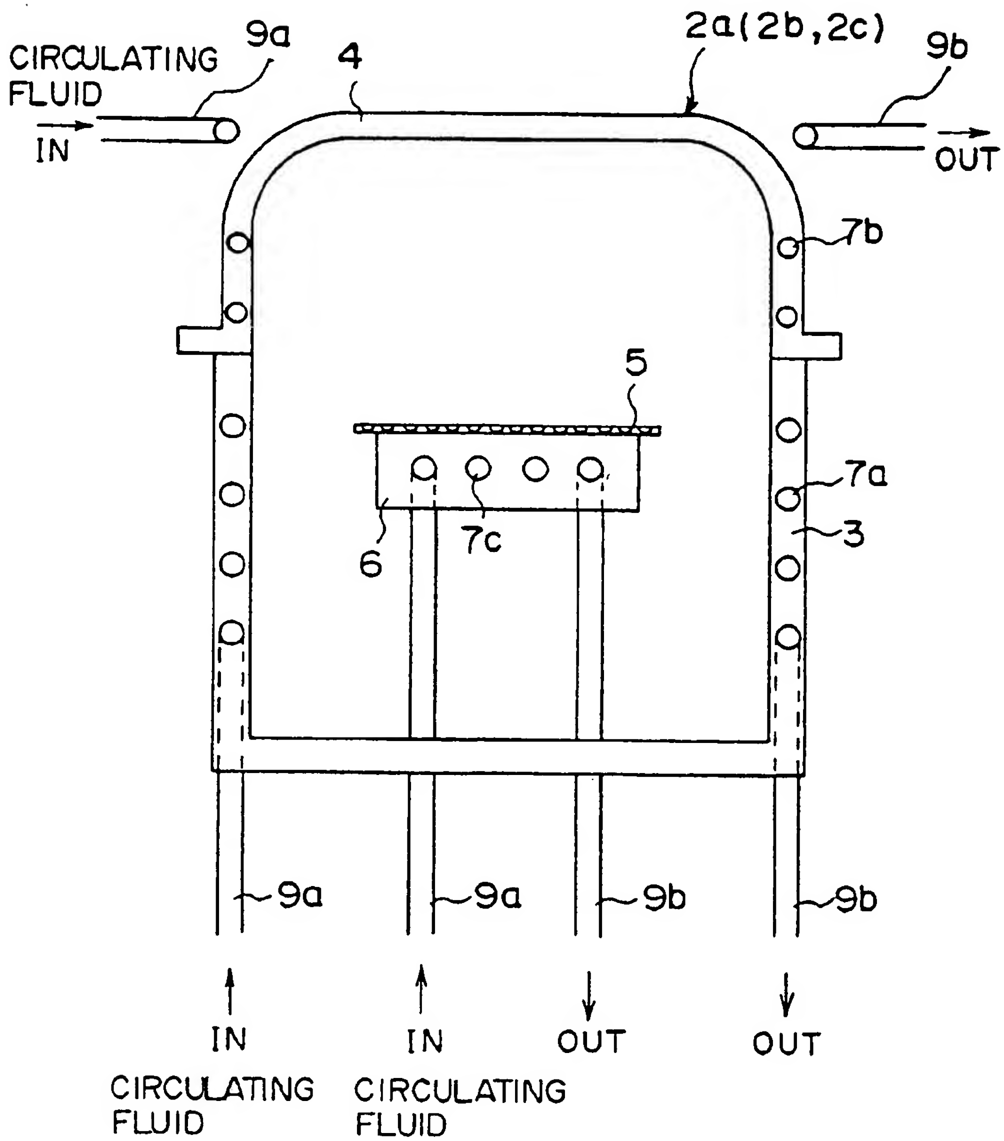


FIG. 3
PRIOR ART

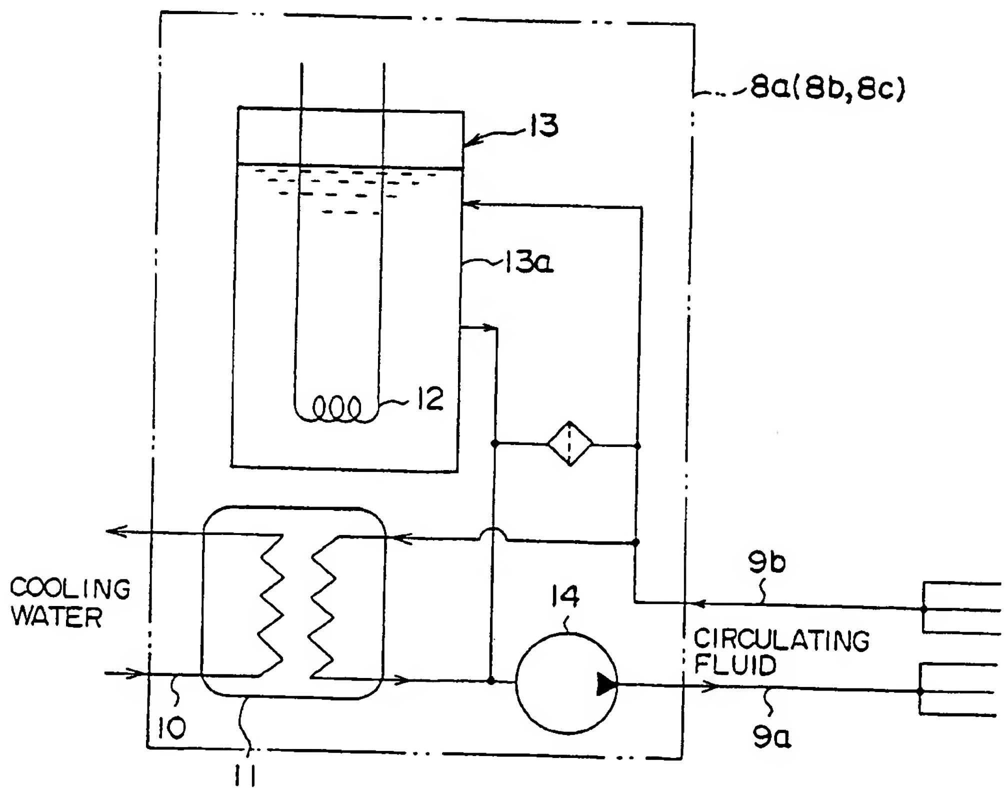


FIG. 4

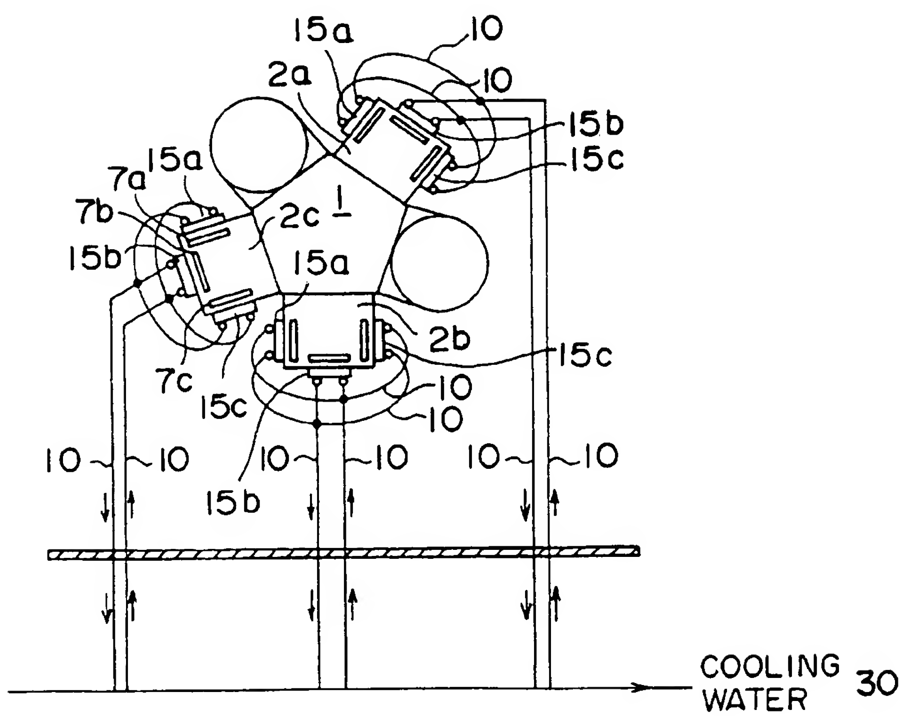

15a
10
2a
10
15b
15c
7a
15a
7b
2c
1
15b
15a
2b
15c
7c
15c
10
10
10
10
10
10
10
10
15b
COOLING WATER
30

FIG. 5

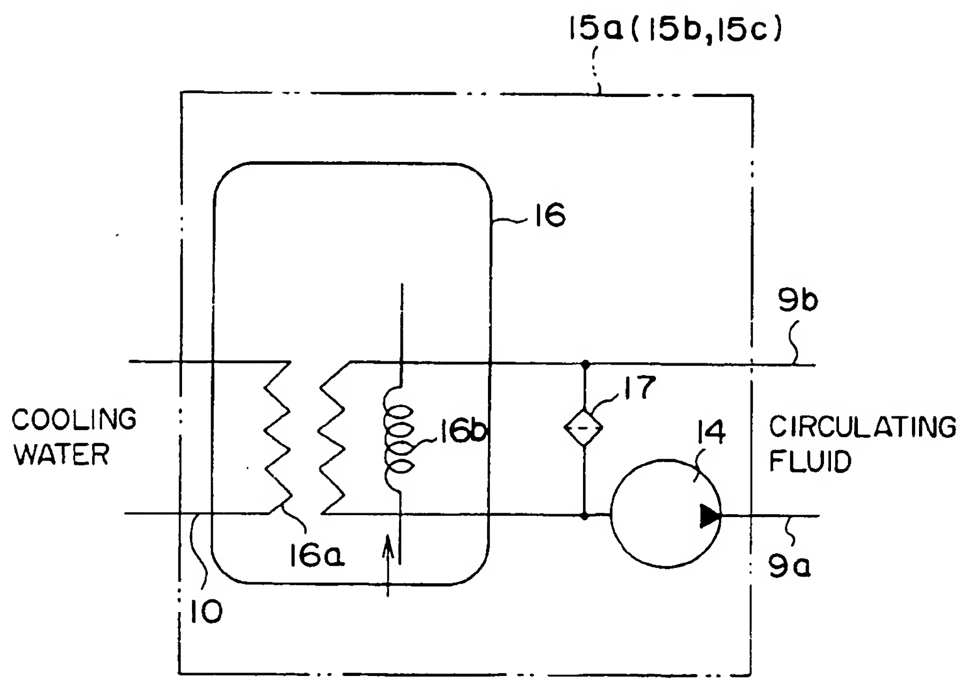

15a(15b,15c)
16
9b
17
COOLING
WATER
16b
14
CIRCULATING
FLUID
16a
9a
10

FIG. 6

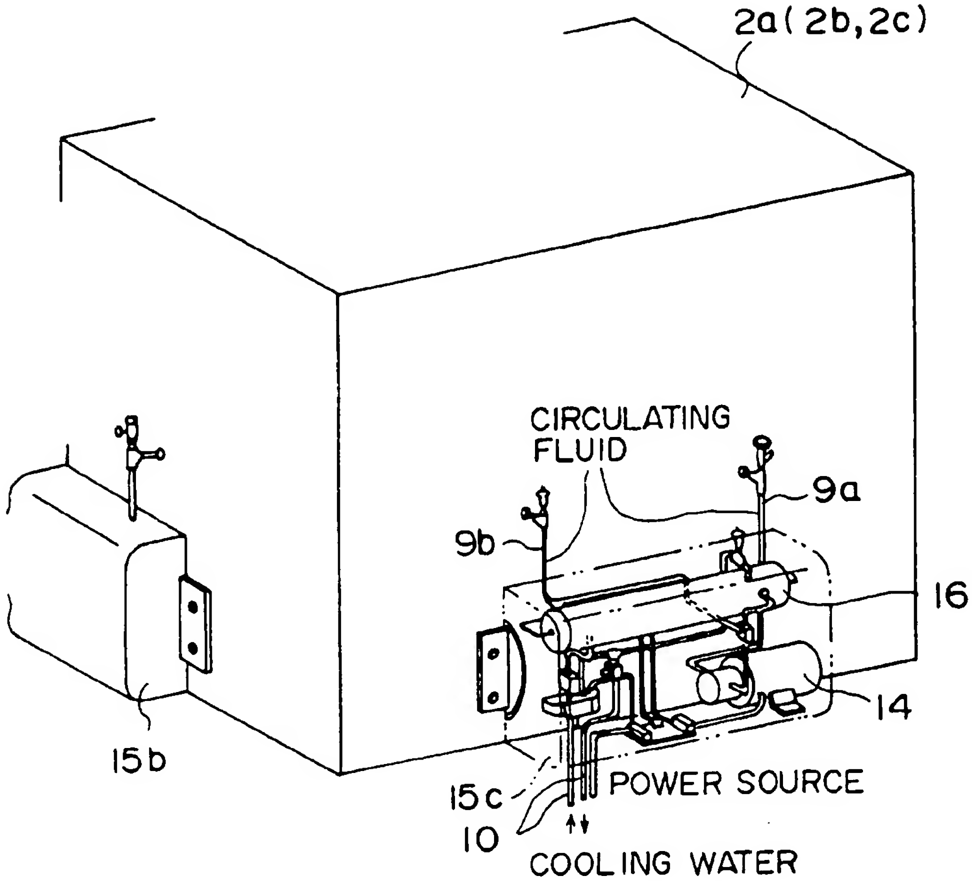

2a(2b,2c)
CIRCULATING FLUID
9a
9b
16
14
15b
15c
10
POWER SOURCE
COOLING WATER

FIG. 7

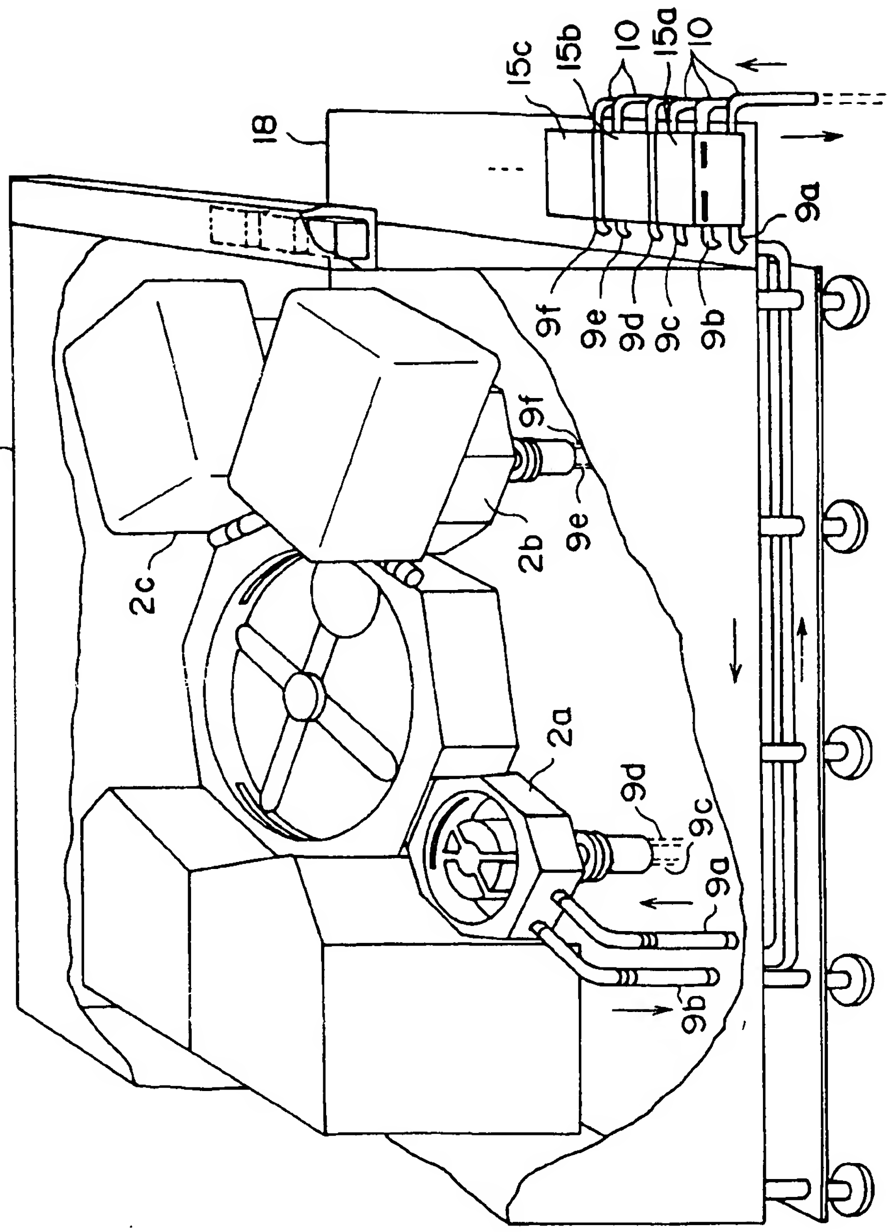


FIG. 8

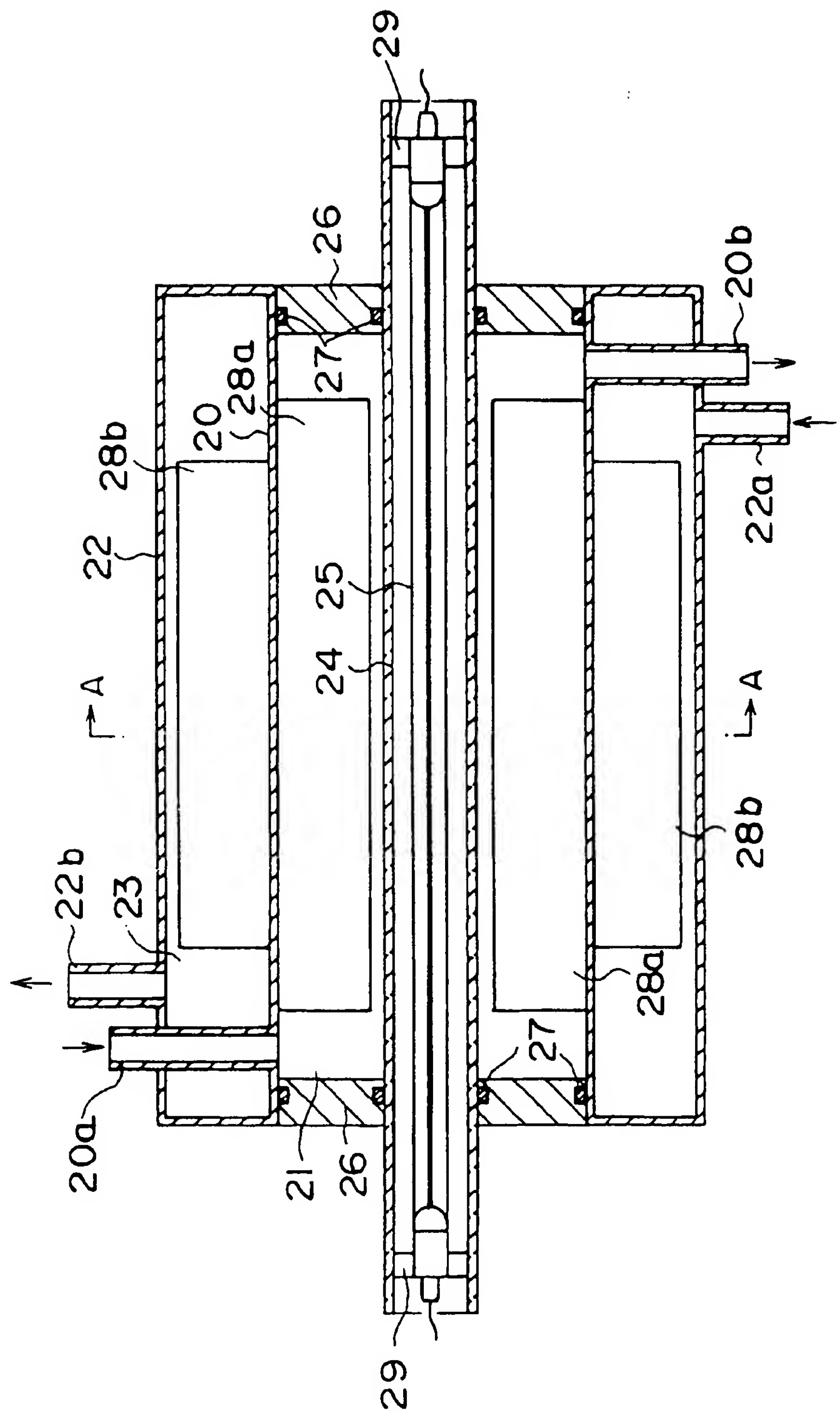


FIG. 9

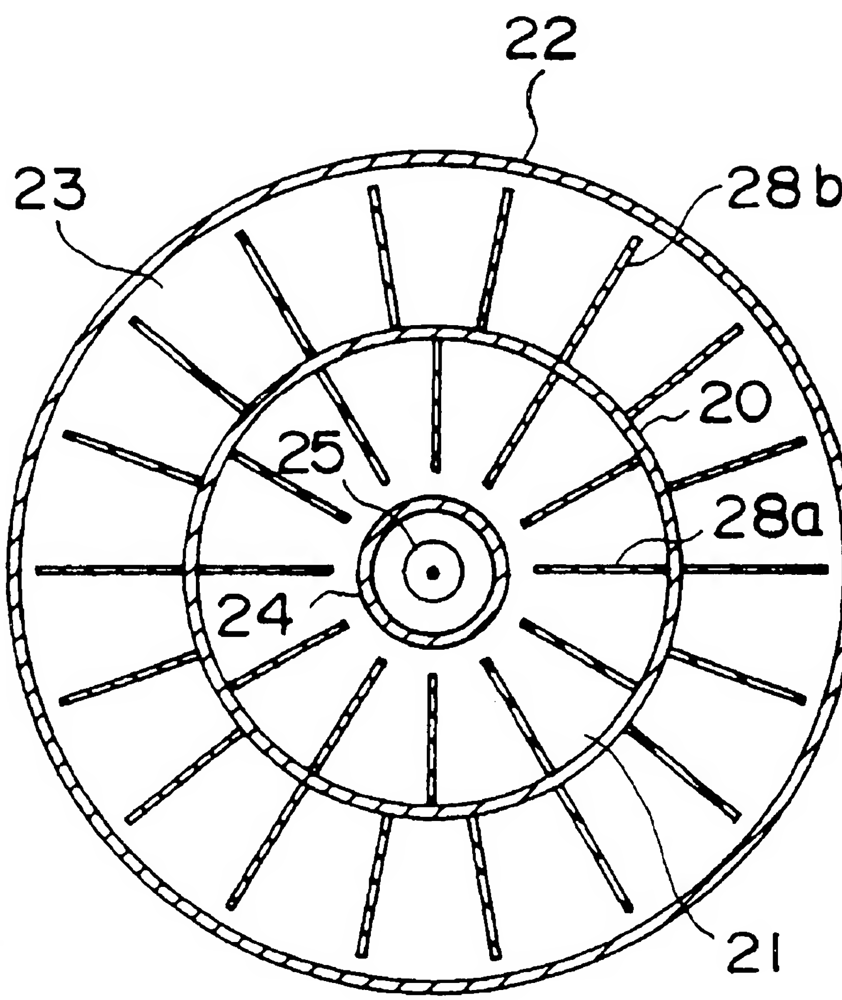


FIG. 10

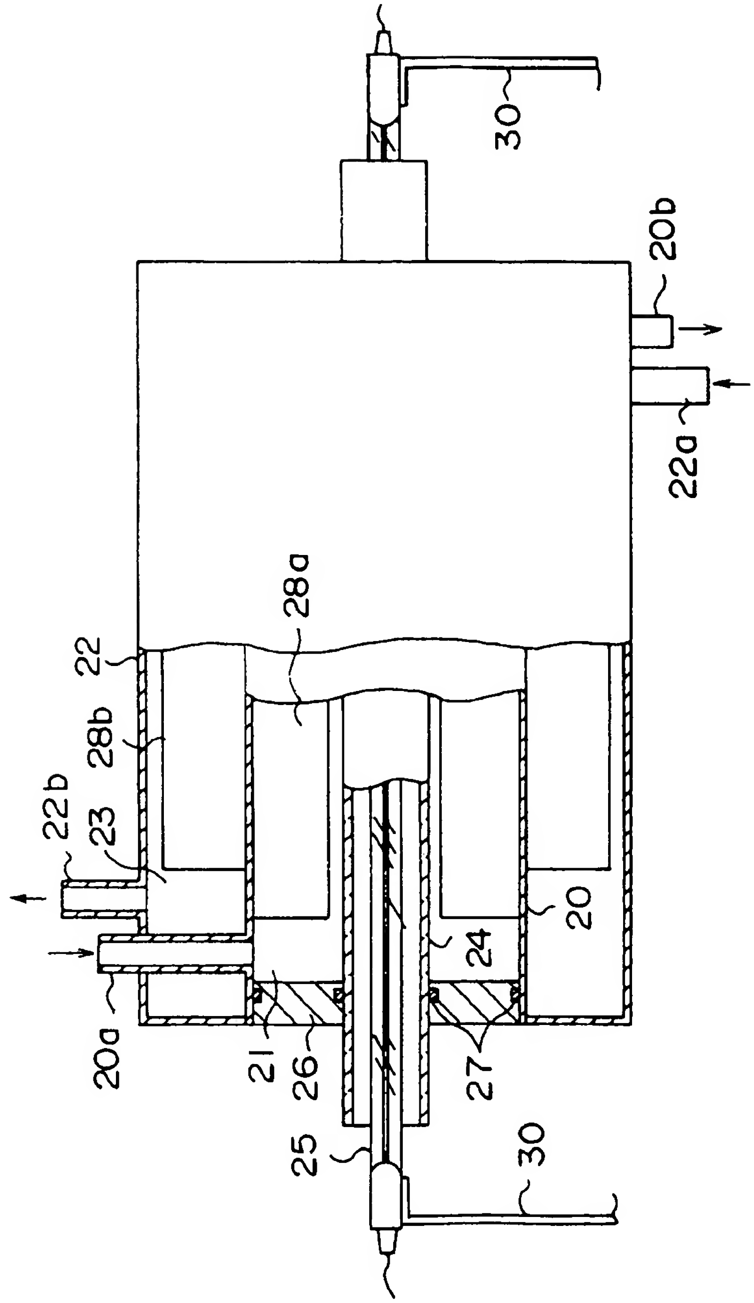


FIG. 11

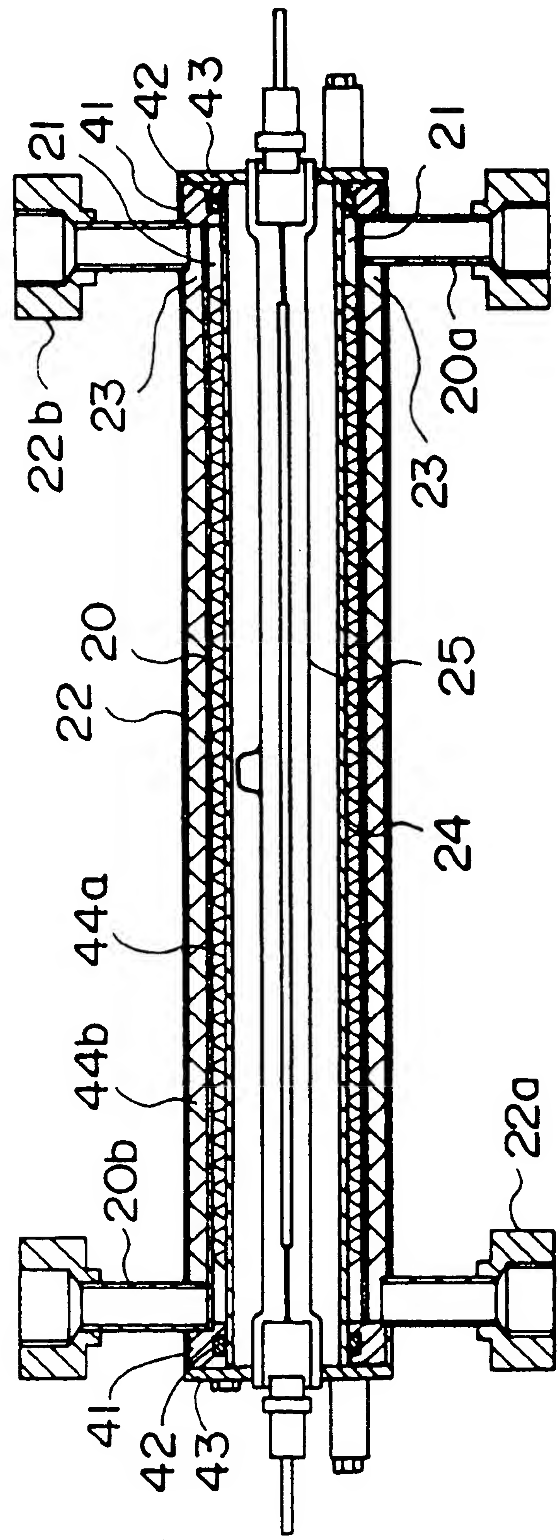


FIG. 12A

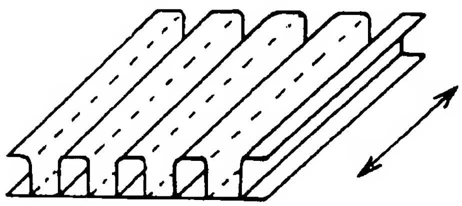


FIG. 12B

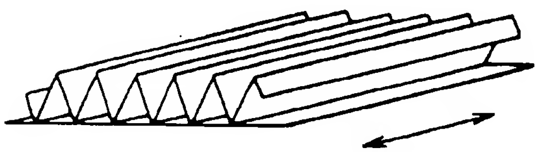


FIG. 12C

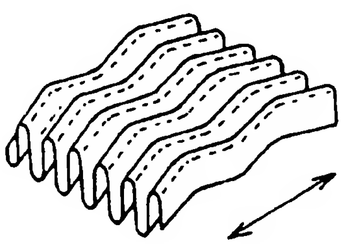


FIG. 12D

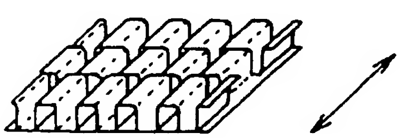


FIG. 12E

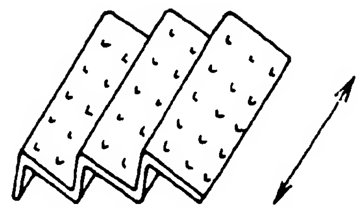


FIG. 12F

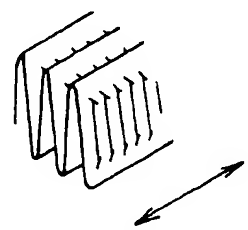


FIG. 12G

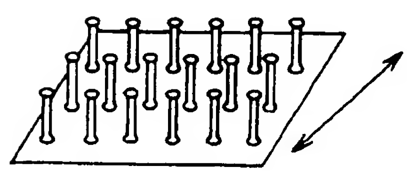
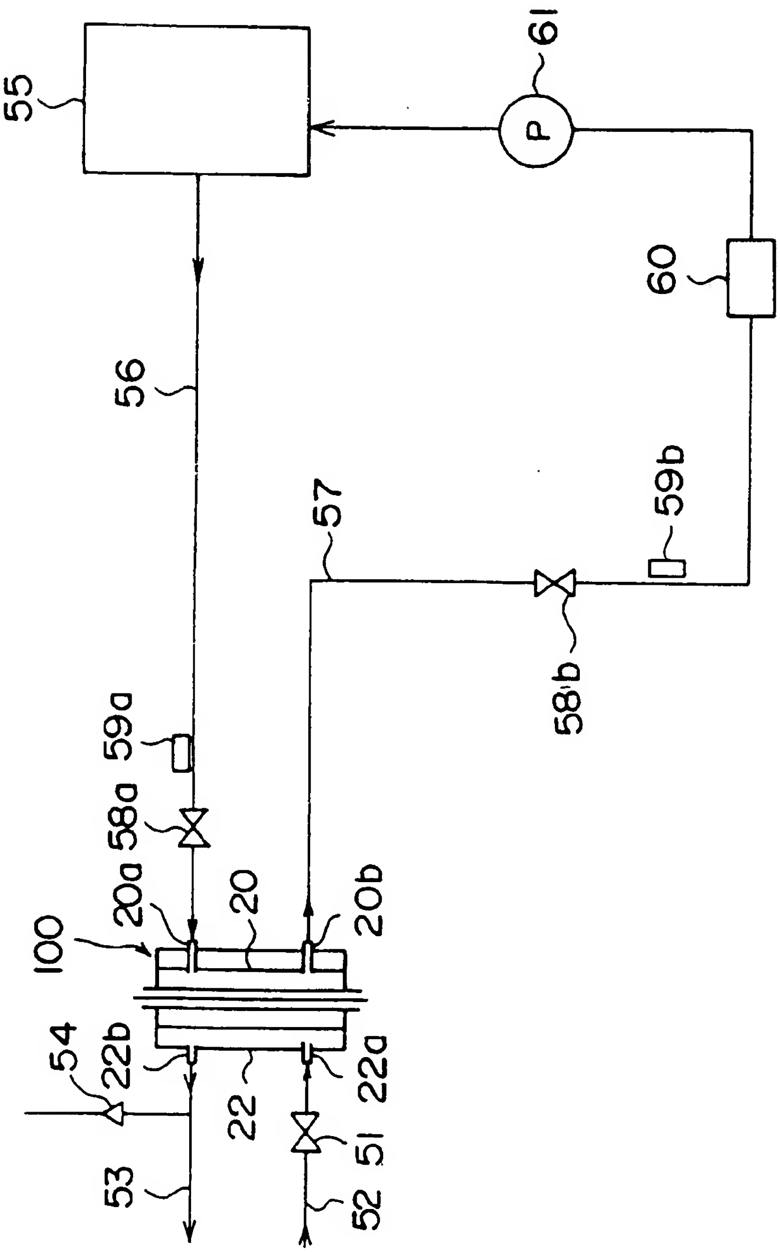


FIG. 13


55
61
P
60
56
57
59b
58b
59a
58a
20a
20
20b
100
54
22b
22
22a
51
52
53

MULTI-TEMPERATURE CONTROL SYSTEM AND FLUID TEMPERATURE CONTROL DEVICE APPLICABLE TO THE SAME SYSTEM

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a multi-temperature control system for controlling temperatures at a plurality of places using circulation of a working fluid, and also relates to a fluid temperature control device which is applicable to the same system.

The multi-temperature control system according to the present invention can be preferably used, for instance, to control temperatures of various portions in a plurality of process chambers (reaction processing chambers) of a semiconductor processing apparatus; without being limited only thereto, however, this system can be applied to the other various reaction processing apparatus.

The fluid temperature control device according to the present invention is applicable not only to the multi-temperature control system of this invention, but also to the other various type temperature control systems.

BACKGROUND OF THE INVENTION

The conventional semiconductor processing apparatus is constructed as shown in FIG. 1, for instance. In more detail, a plurality of process chambers *2a, 2b* and *2c* are arranged around a transfer chamber 1. A wafer (not shown) to be processed is carried from a process chamber to another process chamber via the transfer chamber 1 by use of a carrier robot (not shown) provided within the transfer chamber 1. A specific reaction is performed on the wafer in each of the process chambers *2a, 2b* and *2c,* respectively.

FIG. 2 shows a construction of each process chamber, which is composed of a chamber wall 3, a chamber cover which functions as an anode, and a wafer support base 6 which functions as a cathode. The chamber wall 3, the chamber cover 4 and the wafer support base 6 are provided with pipe lines *7a, 7b* and *7c* through which working fluids for controlling temperature flow, respectively. The working fluid flowing through each of these pipe lines *7a, 7b* and *7c* controls each temperature of the chamber wall 3, the chamber cover 4 and the wafer support base 6 to each of specific target temperatures T1, T2 and T3 separately.

The prior art temperature control system applied to the semiconductor processing apparatus, as shown in FIG. 1, comprises three temperature control machines *8a, 8b* and *8c* in each of which each of the target temperatures T1, T2 and T3 is set. Each of the temperature control machines *8a, 8b* and *8c* supplies each temperature-controlled working fluid to all of the process chambers *2a, 2b* and *2c* of the semiconductor processing apparatus. For instance, the first temperature control machine *8a* supplies the working fluid to the chamber walls 3 of all the process chambers *2a, 2b* and *2c* through three pairs of fluid circulation pipes *9a, 9b; 9a, 9b;* and *9a, 9b*. In the same way, the second temperature control machine *8b* supplies the working fluid to the chamber covers 4 of all the process chambers *2a, 2b* and *2c;* and the third temperature *8c* supplies the working fluid to the wafer support bases 6 of all the process chambers *2a, 2b* and *2c*.

As shown in FIG. 3, each temperature control machine is provided with a heat exchanger 11 for cooling the working fluid, a heater 13 for heating the working fluid, and a pump 14 for circulating the temperature-controlled working fluid through the circulation pipes *9a* and *9b*. The heat exchanger 11 cools the working fluid by passing cooling water through a cooling water pipe 10. The heater 13 accumulates the working fluid in a tank *13a* and then heats the working fluid in the tank *13a* by an electric heater 12.

As described above, in the prior art temperature control system used for the semiconductor processing apparatus, one temperature control machine is used in common for a plurality of the process chambers; that is, one temperature control machine controls temperature at specific portions of a plurality of process chambers in centralization manner.

Accordingly, since the target temperature is controlled in common at the temperature-controlled portion of each of a plurality of the process chambers, it is impossible to change each target temperature at each temperature-controlled portion according to each process chamber in principle. In addition, it is also impossible to control all the temperatures of the portions of all the process chambers at the same level accurately. This is because the shape, operating condition, circulation pipe length, pressure loss, etc. differ according to each process chamber, so that the temperature of the working fluid differs slightly according to each process chamber.

Here, in order to control each target temperatures according to each process chamber, it may be possible to consider such a method of controlling the flow rate of the working fluid according to each chamber. In this method, however, since the control construction may be considerably complicated, and further since the fluid flow rate control may be interfered with each other between the process chambers, it is difficult to control the temperature accurately.

Further, in the prior temperature control system, since the centralized-control is executed, as shown in FIG. 1, the temperature control machines are inevitably located an appropriate distance apart from the semiconductor processing apparatus. As a result, the fluid circulation pipes are inevitably lengthened, and further the quantity of working fluid to be used increases. It is preferable to use as the working fluid a non-active fluid such as GALDEN (Trademark) or FLUORINERT (Trademark). However, since these non-active working fluids are considerably expensive, it is not preferable to use a large quantity of these fluid. Therefore, in the prior art temperature control system, a low-cost working fluid such as ethylene glycol or water is used, excepting special circumstances. However, since the low-cost working fluid produces ions by the influence of plasma generated within the process chamber and thereby the process chamber is easily corroded, a deionizing instrument of large size and of high cost is additionally required.

Further, in the prior art temperature control system, since the fluid circulation pipes are relatively long, the thermal loss is large in the circulation pipes. As a result, a relatively large heat capacity is necessary for each temperature control machine. In summary, the size of the prior art temperature control system is inevitably increased due to the large heat capacity and the installation place thereof.

As described above, working fluids are preferably used to control the temperatures of various objects such as a wall of a processing chamber of a semiconductor processing apparatus, air supplied to a constant temperature chamber and the like. The temperature of each working fluid must be controlled to a target temperature according to each object.

The prior art devices for controlling the temperature of the working fluid are disclosed in Japanese Published Unexamined (Kokai) Patent Application Nos. 58-219374, 7-280470, and 5-231712, for instance.

The fluid temperature control device disclosed by Japanese Published Unexamined (Kokai) Patent Application No.

58-219374 comprises a roughly cylindrical water flow passage which is partitioned finely so that water can flow in spiral state therethrough. A long and narrow electric heater is inserted into the central portion of the cylindrical water flow passage. Further, the outer circumferential surface of this cylindrical water flow passage is covered by another roughly cylindrical cooling medium flow passage which is also partitioned so that a condensed cooling medium can flow also in spiral state therethrough. Therefore, the water flowing through the water flow passage can be heated and cooled by the electric heater and the condensed cooling medium.

In the fluid temperature control device disclosed by Japanese Published Unexamined (Kokai) Patent Application No. 7-280470, an electric heater is inserted into a central portion of a pipe through which a working fluid flows, and the outer circumference of the pipe is covered by a large diameter pipe through which cooling water can flow. Therefore, the temperature of the working fluid flowing through the pipe can be controlled by the electric heater and the cooling water.

In the fluid temperature control device disclosed by Japanese Published Unexamined (Kokai) Patent Application No. 5-231712, a hollow pipe formed of quartz glass is arranged at the central portion of a cylindrical vessel through which a working fluid flows, and an infrared ray lamp is inserted into the hollow pipe. Therefore, the fluid in the vessel can be heated by the radiation heat emitted by the lamp.

In the device disclosed by Japanese Published Unexamined (Kokai) Patent Application No. 7-280470, since thermal conduction from the heater to the cooling water is utilized, there inevitably exists a non-uniforminity of the temperature of the working fluid according to the distance from the heat source. For instance, the fluid temperature is relatively high in the vicinity of the heater but low at a place remote from the heater.

In the device disclosed by Japanese Published Unexamined (Kokai) Patent Application No. 58-219374, since the fluid may be stirred when it flows helically, the non-uniformity of the fluid temperature may not occur substantially. However, since the structure of the helical flow passage is complicated, the manufacturing and maintenance process thereof is troublesome.

Further, with the devices utilizing thermal conduction, since temperature becomes locally very high in the vicinity of the heater, it is necessary to suppress the heater temperature so that the working fluid passing near the heater will not be boiled or that the heater temperature will not exceed the heat resistance limit of the materials of the heater and other vicinal elements. As a result, it is rather difficult to supply a large quantity of heat to the working fluid and further to set the target temperature of the working fluid at a high value.

The device disclosed by Japanese Published Unexamined (Kokai) Patent Application No. 5-231712 utilizes heat radiation (i.e., heat supply by electromagnetic waves, mainly by infrared rays) instead of thermal conduction. In this device, since the radiation heat of infrared rays can be emitted to all the places in the fluid uniformly, there exists no problem with respect to the non-uniformity of temperature. Further, even if the quantity of radiation heat increases, since the vicinity of the light source will not be heated up to a high temperature locally, it is possible to supply a large quantity of heat to the fluid and further to set the target temperature at a high value. With this device, however, when using as the working fluid a substance having an extremely low light absorbability, it is difficult to heat the fluid by the radiation heat.

OBJECTS OF THE INVENTION

One object of the present invention is to provide a multi-temperature control system for controlling temperatures at a plurality of places using circulation of a working fluid, which is able to control each temperature at each place accurately without increasing the system size and the quantity of the working fluid to be used.

Another object of the present invention is to provide a fluid temperature control device which is preferably applicable to the above described small-sized multi-temperature control system.

A further object of the present invention is to provide a fluid temperature control device which is simple in structure, less in fluid temperature non-uniformity, and able to heat a fluid having a low light absorbability.

SUMMARY OF THE INVENTION

The multi-temperature control system according to the first aspect of the present invention, in order to control temperatures at a plurality of places using circulation of a working fluid, comprises a plurality of temperature control machines each assigned to each of the places. Each temperature control machine assigned to each place is provided with a pair of fluid circulation pipes for circulating the working fluid which is exclusively for each place, and each machine controls the temperature of the working fluid within each pair of the fluid circulation pipes individually.

With this distributed or decentralized type system, each temperature control machine can be arranged in the vicinity of each place to which each machine is assigned. Therefore, the length of the fluid circulation pipes can be shortened, so that the quantity of the working fluid used can be reduced. As a result, it is possible to use a high performance working fluid such as GALDEN or FLUORINERT, which is high in cost but does not require any ionization instrument.

Each temperature control machine controls each dedicated working fluid for each place independently, and since the fluid circulation pipes is short, its heat loss is small and the temperature control response is high, so that an accurate temperature control operation can be achieved.

The size of each temperature control machine can be small, since each machine does not need large thermal capacity nor large power for circulating the working fluid, and does not consume large electric power. The small-sized temperature control machines can be arranged at a plurality of places separately, their fluid circulation pipes can be shortened and no ionization instrument is necessary, so that the overall size of the multi-temperature control system can be reduced.

The temperature control machines may use a cooling liquid in order to cool their working fluid. In this case, these machines can commonly use the same cooling liquid source, thus simplifying the construction of the cooling liquid system.

A preferred construction of the temperature control machine comprises: an inner vessel having an inner space for passing the working fluid; a heater arranged in the inner space; and an outer vessel surrounding the inner vessel and having an outer space for passing cooling water outside the inner vessel. In the above constructed temperature control machine, since the working fluid can be heated and cooled within the single vessel, the size of the temperature control machine can be reduced. It is preferable to use as the heater a lamp which radiates infrared rays. In the case that the infrared ray lamp is used, a large heating capacity can be

obtained even if the lamp is small-sized, so that the size of the temperature control machine can be further reduced. The small-sized temperature control machines can be easily arranged to their assigned places separately.

The distributed type multi-temperature control system according to the present invention can be applied to a reaction processing apparatus having a plurality of process chambers such as the semiconductor processing apparatus. In this case, a dedicated temperature control machine used for only a single process chamber can be arranged in the vicinity of each process chamber. When a single process chamber has a plurality of temperature-controlled portions, a plurality of the temperature control machines each of which is dedicated to each of the temperature-controlled portions can be arranged in the vicinity of the process chamber. In this case, each dedicated temperature control machine can be arranged in the vicinity of each of the portions separately.

The fluid temperature control device according to the second aspect of the present invention comprises: a transparent cylinder; a lamp arranged within the transparent cylinder, for radiating infrared rays; a cylindrical vessel arranged so as to surround said transparent cylinder and having an inner space between said transparent cylinder and said cylindrical vessel; a fluid inlet port for passing a fluid into the inner space; a fluid outlet port for passing the fluid from the inner space; and inner fins arranged in the inner space in contact with an inner circumferential surface of said cylindrical vessel.

In the fluid temperature control device according to the present invention, the fluid flowing through the inner space can be heated by radiation heat emitted from the lamp. Since the radiation heat is utilized, the temperature non-uniformity is relatively small. Further, since the fins are arranged in the inner space, even if the fluid is a substance having an extremely low light absorbability, the radiation heat can be received by the fins and then transmitted to the fluid, so that the fluid of low light absorbability can be also heated.

In order to increase the heating efficiency and further to eliminate the temperature non-uniformity, it is preferable that the fins are arranged dispersively all over the inner space. Further, it is further preferable that the fins are arranged dispersively all over the inner space at substantially a uniform density.

In the case that the fluid is a substance having a somewhat high light absorbability, it is preferable that the fins are extending radially along radiation direction of the infrared rays from the lamp. In this case, since the infrared rays can be emitted to all over the fluid without being blocked by the fins, the fluid can be heated uniformly.

In order to reduce the pressure loss of the fluid caused by the fins, it is preferable that the fins are extending axially roughly along flow direction of the fluid.

Further, the fluid temperature control device according to the present invention may further comprise: an outer cylinder surrounding said cylindrical vessel and having an outer space between said cylindrical vessel and said outer cylinder; a cooling liquid inlet port for passing a cooling liquid into the outer space; and a cooling liquid outlet port for passing the cooling liquid from the outer space. With this device, the fluid can be not only heated but also cooled.

In this case, in order to increase the cooling efficiency and further to decrease the temperature non-uniformity during cooling, this device preferably further comprises outer fins arranged in the outer space in contact with an outer circumferential surface of the cylindrical vessel. It is preferable that the outer fins are arranged dispersively all over the outer space at a substantially uniform density.

The fluid temperature control device according to the present invention can be applied not only to the distributed type multi-temperature control system according to the present invention but also to other various temperature control applications.

The other features and the objects of the present invention will be clarified under the detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plane view showing the semiconductor processing apparatus which uses the prior art temperature control system.

FIG. **2** is a cross-sectional view showing the structure of the process chamber.

FIG. **3** is a circuit diagram of the prior art temperature control machine.

FIG. **4** is a plane view showing the semiconductor processing apparatus which uses an embodiment of the temperature control system according to the present invention.

FIG. **5** is a circuit diagram of the temperature control machine used for the embodiment shown in FIG. **4**.

FIG. **6** is a perspective view showing the mounting example of the temperature control machines of the same embodiment.

FIG. **7** is a perspective view showing another mounting example of the temperature control machines.

FIG. **8** is a longitudinal cross-sectional view showing the fluid temperature control device used for the temperature control machine shown in FIG. **5**.

FIG. **9** is a cross-sectional view taken along the line A—A in FIG. **8**.

FIG. **10** is a partial cross-sectional view showing a modification of the lamp supporting portion of the fluid temperature control device.

FIG. **11** is a longitudinal cross-sectional view showing another embodiment of the fluid temperature control device.

FIGS. **12**(A) to **12**(G) are perspective views showing various types of fins.

FIG. **13** is a circuit diagram showing the temperature control system using the fluid temperature control device according to the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

FIG. **4** shows an entire construction of an embodiment of the multi-temperature control system according to the present invention, which is applied to the semiconductor processing apparatus. Here, since the semiconductor processing apparatus is substantially the same as the prior art apparatus shown in FIGS. **1** and **2**, the same reference numerals have been retained for similar elements or parts having the same functions as with the case of the prior art apparatus, without repeating the similar description thereof.

As shown in FIG. **4**, a set of three small-sized temperature control machines **15***a*, **15***b* and **15***c* are provided for each of the three process chambers **2***a*, **2***b* and **2***c* of the semiconductor processing apparatus, respectively. In other words, one set of three temperature control machines **15***a*, **15***b* and **15***c* are provided for the first process chamber **2***a*. In the same way, another set of three temperature control machines

15*a*, 15*b* and 15*c* are provided for the second process chamber 2*a* and a further other set of three temperature control machines 15*a*, 15*b* and 15*c* are provided for the third process chamber 2*c*.

Each of the temperature control machines 15*a*, 15*b* and 15*c* is provided with its' own fluid circulation pipes (not shown in FIG. 4) independently from the other temperature control machines, to supply a working fluid such as FLUORINERT to each of the process chambers 2*a*, 2*b* and 2*c*, independently. Each of the temperature control machines 15*a*, 15*b* and 15*c* supplies the working fluid to only the process chamber on which each machine is mounted, without supplying the working fluid to the other process chambers. Further, in the three temperature control machines 15*a*, 15*b* and 15*c* mounted on one process chamber, the first temperature control machine 15*a* supplies the working fluid to the pipe line 7*a* of the chamber wall 3 (shown in FIG. 2); the second temperature control machine 15*b* supplies the working fluid to the pipe line 7*b* of the chamber cover 4; and the third temperature control machine 15*c* supplies the working fluid to the pipe line 7*c* of the wafer support base 6, respectively. In summary, a single temperature control machine is assigned exclusively to each portion at which temperature is to be controlled in the semiconductor processing apparatus.

These temperature control machines 15*a*, 15*b* and 15*c* can be mounted on outer wall surfaces of the process chambers, for instance;. without being limited to only the outer wall surfaces thereof, however, the temperature control machines can be preferably disposed at such positions as are close to each of the process chambers so that the length of each fluid circulation pipe is enough short. From the same point of view, it is preferable that each of the temperature control machines 15*a*, 15*b* and 15*c* is disposed at such position as is as close as possible to each of the pipe lines 7*a*, 7*b* and 7*c*.

These nine temperature control machines 15*a*, 15*b* and 15*c* are connected to a common cooling liquid source 30 via a pair of different cooling liquid circulation pipes 10. As the cooling liquid, water can be used, for instance; however, another substance can be of course used.

All of the temperature control machines 15*a*, 15*b* and 15*c* are of the substantially same construction. As shown in FIG. 5, each temperature control machine is provided with a fluid temperature control device 16 for heating and cooling the working fluid and a pump 14 for circulating the working fluid through the fluid circulation pipes 9*a* and 9*b*. The fluid temperature control device 16 is composed of a cooling section 16*a* for cooling the working fluid by cooling water and a heating section 16*b* for heating the working fluid. In the case that ethylene glycol or water is used as the working fluid, a deionizing instrument 17 is connected between the supply pipe (9*a*) and the return pipe (9*b*) of the fluid circulation pipes 9*a* and 9*b*. In the case that the non-active substance such as FLUORINERT is used as the working fluid, the deionizing instrument 17 is not required.

FIG. 6 shows a method of mounting each of the temperature control machines 15*a*, 15*b* and 15*c* on each of the process chambers 2*a*, 2*b* and 2*c*.

As shown, the temperature control machines 15*a*, 15*b* and 15*c* are fixed to the outer surfaces of the side walls of each of the process chamber 2*a*, 2*b* and 2*c*, respectively. Each pair of fluid circulation pipes 9*a* and 9*b* extending from each of the temperature control machines 15*a*, 15*b* and 15*c* are introduced into the side wall of the process chamber, and then connected to each of the pipe lines 7*a*, 7*b* and 7*c* as shown in FIG. 2, respectively.

A pair of cooling liquid circulation pipes 10 extend from each temperature control machine 15*a*, 15*b* and 15*c*. As shown in FIG. 4, these cooling liquid circulation pipes from the temperature control machine 15*a*, 15*b* and 15*c* are arranged together to be one pair of pipes for each chamber which are connected to a common cooling liquid source 30. Alternatively, it is possible to connect each cooling liquid circulation pipe 10 of each temperature control machine to the common cooling liquid source 30 directly. In the case that the target temperatures of the three temperature control machines 15*a*, 15*b* and 15*c* are different from each other for instance, it is also possible to connect the cooling liquid circulation pipes of the three temperature control machines 15*a*, 15*b* and 15*c* in series so that the cooling water flows through these pipes in order in the following manner: the cooling water first flows from the cooling liquid source 30 into the temperature control machine of the lowest target temperature, secondly is passed through the temperature control machine of the medium target temperature, and lastly through the temperature control machine of the highest target temperature to be returned to the cooling water source 30.

Although the cooling liquid is used in common for a plurality of the temperature control machines 15*a*, 15*b* and 15*c*, as described above, as far as the flow rate of the cooling liquid is not excessively slow, the temperature fluctuations of the cooling liquid is small. Further, even if the temperature of the cooling liquid fluctuates slightly, since each temperature control machine 15*a*, 15*b* or 15*c* can control the temperature to the optimum conditions individually, it is possible to control each temperature of each working fluid accurately.

Further, without being limited only to the side walls of the process chamber, the temperature control machines 15*a*, 15*b* and 15*c* can be mounted on the bottom wall or the top wall or the adjacent floor, etc.; that is, at any places in the vicinity of the process chamber at which the fluid liquid circulation pipes can be shortened sufficiently. For example, In another embodiment shown in FIG. 7, a shelf 18 is provided on a flank of a housing shell 17 of the semiconductor processing apparatus which has a plurality of the processing chambers 2*a*, 2*b* and 2*c*, and a plurality of the temperature control machines 15*a*, 15*b* and 15*c* are mounted on the shelf 18 in a row. Each pair of the fluid circulation pipes 9*a*, 9*b*, 9*c*, 9*d*, 9*e* and 9*f* extending from each of the temperature control machines 15*a*, 15*b* and 15*c* are introduced into the inside of the housing shell 17 to be connected to each of the pipes 7*a*, 7*b* and 7*c*, as shown in FIG. 2, of the processing chambers 2*a*, 2*b* and 2*c*. In this embodiment, the temperature control machines 15*a*, 15*b* and 15*c* are arranged in the vicinity of the semiconductor processing apparatus, so that their fluid circulation pipes 9*a*, 9*b*, 9*c*, 9*d*, 9*e* and 9*f* are sufficiently short and the temperatures of the working fluids in these pipes can be controlled accurately.

In the above embodiments, each temperature control machine controls the temperature at only one place of the one processing chamber; without being limited only to this, however, each temperature control machine may control the temperature of a plurality of places in the semiconductor processing apparatus. Further, in the above-mentioned embodiment, although all the portions of all the process chambers are controlled by the circulating working fluid, it is also possible to control the temperatures of some portions by another method without using the working fluid. For instance, in the case that there exists a chamber or a portion to be heated up to a temperature higher than 100° C., an infrared ray lamp can disposed at this chamber or this

portion, instead of the above-mentioned temperature control machine, so that this infrared lamp heats the chamber or the portion directly.

FIGS. 8 and 9 show a embodiment of the fluid temperature control device 16 shown in FIG. 5. FIG. 8 is a longitudinal cross-sectional view showing the same device and FIG. 9 is a lateral cross-sectional view taken along the line A—A in FIG. 8.

As shown in these drawings, the fluid temperature control device 16 has two large (outer) and small (inner) cylindrical vessels 20 and 22. The inner vessel 20 is formed with an inner space 21 and two closed end surfaces. The outer vessel 22 is formed with an outer space 23 enclosing the inner vessel 20 and two closed end surfaces. Further, the inner vessel 20 is formed with a working fluid inlet port 20*a* at a position close to one end of the circumferential wall thereof and with a working fluid outlet port 20*b* at a position close to the other end of the circumferential wall thereof in such a way that two ports 20*a* and 20*b* are arranged symmetrically opposite to each other with respect to the central axis thereof. In the same way, the outer vessel 22 is formed with a cooling liquid inlet port 22*a* at a position close to one end of the circumferential wall thereof and with a cooling liquid outlet port 22*b* at a position close to the other end of the circumferential wall thereof in such a way that two ports 22*a* and 22*b* are arranged symmetrically opposite to each other with respect to the central axis thereof.

The inner vessel 20 is made of a material having an excellent corrosion resistance, an excellent thermal conductivity and an excellent moldability, for instance such as aluminum, copper, stainless steel, etc. The outer vessel 22 can be made of the same material or another material having an excellent corrosion resistance but a low thermal conductivity such as plastic, vinyl chloride, ceramics, etc. The junction portions between the inner vessel 20 and outer vessels 22 are sealed by welding or soldering or other appropriate method so as not to leak the cooling liquid.

Within the inner space 21 of the inner vessel 20, a transparent cylinder 24 is arranged along the central axis thereof so as to pass through both the end walls 26 of the inner vessel 20. A heating lamp 25 is inserted into the transparent cylinder 24. The transparent cylinder 24 is made of a material having an extremely high light transmissibility and a high heat resistance such as quartz glass. As the heating lamp 25, the lamp which can emit a great quantity of infrared rays is preferable. For instance, a heating halogen lamp is used. The heating lamp 25 is supported by two bushes 29 within the transparent cylinder 24 at the central position thereof in such a way as not to be brought into contact with the transparent cylinder 24.

The two end walls 26 of the inner vessel 20 are made of a material having an appropriate elasticity and a sufficient heat resistance such as a hard rubber, plastic, metal, etc. Further, two large- and small-diameter sealing members 27 such as O-rings are disposed on both the inner and outer circumferential surfaces of the two end walls 26, respectively in order to seal the gaps between the end walls 26 and the inner vessel 20 and between the end walls 26 and the transparent cylinder 24.

A plurality of inner fins 28*a* are fixed on the inner circumferential surface of the inner vessel 20, and a plurality of outer fins 28*b* are fixed on the outer circumferential surface of the inner vessel 20. The inner and outer fins 28*a* and 28*b* extend in a direction crossing a flow direction (substantially parallel to the central axis of the, vessel 20) of the working fluid and the cooling water at an appropriate angle so that good thermal exchange efficiencies between the inner fins 28*a* and the working fluid and between the outer fines 28*b* and the cooling water are obtained. Further, the inner fins 28*a* extend in the radial direction of the inner space 21, that is, in the radiation direction of the infrared rays of the lamp 25. However, when using the working fluid having a low light absorbability, the inner fans 28*a* may extend in a direction crossing the radiation direction of the infrared rays. In the same way, the outer fins 28*b* extend in the radial direction of the inner space 21. However, this arrangement of the outer fins 28*b* is not necessarily required. The inner fins 28*a* are arranged being separated at regular angular intervals (i.e., at substantially uniform arrangement density) all over the inner space 21, and the outer fins 28*b* are also arranged being separated at regular angular intervals all over the outer space 23. These fins 28*a* and 28*b* are made of a material having a high thermal conductivity and excellent corrosion resistance and moldability such as aluminum, copper, stainless steel, etc. Further, it is preferable that the material has a high absorbability of infrared rays.

There exists a slight gap between each end of each of the inner fins 28*a* and the outer circumferential surface of the transparent cylinder 24. In the same way, there exists a slight gap between each end of each of the outer fins 28*b* and the inner circumferential surface of the outer vessel 22.

In the fluid temperature control device constructed as described above, the working fluid flows from the inlet port 20*a* to the output port 20*b* through the inner space 21, and the cooling liquid flows from the inlet port 22*a* to the output port 22*b* through the outer space 23.

When a target temperature (e.g., 100° C.) of the working fluid is higher than the temperature (e.g., 25° C.) thereof at the inlet port 20*a*, the lamp 25 is turned on. In this case, the cooling liquid is stopped from flowing in general. The infrared rays emitted from the lamp 25 are allowed to be incident upon the inner space 21 through the transparent cylinder 24. Here, if the working fluid is a substance having an extremely low light absorbability (e.g., FLUORINERT), a major part of the emitted infrared rays are absorbed by the fins 28*a*. Therefore, the radiated heat is transmitted from the fins 28*a* to the working fluid, so that the working fluid can be heated. Here, if the working fluid is a substance having an appropriate light absorbability (e.g., water, ethylene glycol, etc.), the emitted infrared rays are absorbed by not only the fins 28*a* but also by the working fluid itself directly, so that the working fluid can be heated by the radiated heat.

The heat quantity of the lamp 25 can be controlled by a combination of a temperature sensor at the outlet port 20*b* and a controller (both not shown). In this case, the duty factor (turn-on time) and/or the light emission quantity of the lamp 25 are adjusted. For instance, the power supplied to the lamp 25 is feedback controlled so that the temperature of the working fluid becomes equal to the target temperature at the outlet port. When the outlet temperature exceeds the target temperature due to an excessive heating or an external factor, the lamp 25 is turned off, and, if not sufficient by only turning off the lamp, the cooling liquid is passed.

When the target temperature (e.g., 30° C.) is lower than the temperature (e.g., 80° C.) of the working fluid at the inlet port, the cooling liquid is passed, and the lamp 25 is turned off in general. Therefore, the heat of the working fluid is transmitted to the cooling liquid through the inner fins 28*a*, the inner vessel 20 and the outer fins 28*b*, so that the working fluid can be cooled. The flow rate of the cooling liquid can be controlled by the above-mentioned controller to match the outlet temperature of the working fluid with the target

temperature. Further, when the outlet temperature of the working fluid drops below the target temperature by the excessive cooling, the lamp **25** is turned on or the flow rate of the cooling liquid is reduced.

As described above, it is possible to control the temperature of the working fluid to the target temperature by controlling the turn-on time of the lamp **25** and the flow rate of the cooling liquid by the controller, that is, by properly heating and/or cooling the working fluid.

As understood by the above description, the working fluid is heated mainly by the radiation heat of infrared rays. The radiation heat can be supplied uniformly to any light absorbing substances existing at any places in the inner space **21** owing to its inherent nature, irrespective of the distance from the lamp **25**. In addition, since the inner fins **28***a* are arranged so as to extend in the radiation direction of the infrared rays from the lamp **25** within the inner space **21**, the infrared rays can be allowed to be incident upon all the places within the inner space **21** without being obstructed by the inner fins **28***a*. As a result, in the case that such a substance as water which can absorb the light appropriately is used as the working fluid, the fluid can be heated substantially uniformly by receiving the radiation heat at all the places within the inner space **21**, so that the fluid temperature rises uniformly. Further, in the case that such a substance as FLUORINERT which can hardly absorb light is used as the working fluid, since the inner fins **28***a* arranged in a uniform density all over the inner space **21** receive the radiation heat uniformly at all the places and then transmit the radiation heat to the working fluid, the fluid can be heated roughly uniformly.

As described above, since the radiation heat from the lamp **25** is supplied to almost all the working fluid roughly uniformly within the inner space **21**, the heat will not be centralized at any specific local position. Further, since a space is formed between the lamp **25** and the transparent cylinder **24**, it is possible to avoid heating up partially the transparent cylinder **24** and the fluid flowing near the transparent cylinder **24** by the thermal conduction. Owing to the above-mentioned facts, it is possible to increase the heat capacity of the lamp **25** to a fairly large value, with the result that a large heating capability can be obtained in spite of a small size of the lamp.

Further, since a gap is formed between the outer fins **28***b* and the outer vessel **22**, it is possible to prevent radiation heat within the inner vessel **20** from being dissipated from the outer fins **28***b* to the outer vessel **22** directly, so that the heating efficiency can be preferably improved. From the same point of view, it is also preferable to make the outer vessel **22** of a material having a low thermal conductivity such as ceramics or plastic. However, as far as no problem arises on the heating efficiency, the outer fins **28***b* can be in contact with the outer vessel **22** and the outer vessel **22** can be made of a material having a high thermal conductivity (e.g., the same material as the inner vessel **20**).

The working fluid is cooled by the thermal conduction through the inner and outer fins **28***a* and **28***b*. Since the fins **28***a* and **28***b* are arranged roughly in a uniform density all over the inner and outer spaces **21** and **23**, respectively, the cooling efficiency is high and the temperature non-uniformity due to the thermal conductivity is small. Further, since there exists the gap between the outer fins **28***b* and the outer vessel **22**, the outer fins **28***b* are not subjected to the influence of the external temperature, this is preferable from the standpoint of cooling efficiency.

In assembly of the fluid temperature control device **16**, the transparent cylinder **24** is inserted into the inner space **21**. Further, in maintenance, the transparent cylinder **24** is pulled out of or inserted again into the inner space **21**. In these insertion and removal works, since there exists a gap between the transparent cylinder **24** and the inner fins **28***a*, these works can be made smoothly. Of course, the inner fins **28***a* can be brought into contact with the transparent cylinder **24**, as far as no problem arises.

As described above, the fluid temperature control device **16** according to the present invention has a large heating and cooling capability for its size. Therefore, this device can be fairly small-sized. Further, since the working fluid can be heated to the target temperature uniformly, the temperature control precision is relatively high. As a result, each of the temperature control machines **15***a*, **15***b* and **15***c* can be small-sized, while keeping the temperature precision at a high level. Therefore, the small-sized temperature control machine **15***a*, **15***b* or **15***c* can be mounted separately on the process chamber **2***a*, **2***b* or **2***c*, or mounted together on the housing shell of the semiconductor processing apparatus as shown in FIG. **7**.

In the practical construction of the fluid temperature control device **16** according to the present invention, various modifications can be made. For instance, as shown in FIG. **10**, the heating lamp **25** can be supported by a bracket **30** attached to the outside of the transparent cylinder **24**. The bracket **30** may be mounted at an appropriate position such as the outer vessel **22** of this control device or a fixture other than this control device.

FIG. **11** shows another embodiment of the fluid temperature control device in which the cylindrical inner vessel **20** is inserted into the cylindrical outer vessel **22** coaxially with the outer vessel **22**, and two doughnut-shaped bushes **41** are attached to both ends of the outer vessel **22**. These bushes **41** close the outer space **23** by the side surfaces thereof and further support the transparent cylinder **24** by the inner circumferential surfaces thereof. Two junction portions between the bushes **41** and the transparent cylinder **4** are sealed by two O-rings **42**, respectively. Two circular outer bushes **43** each having a central hole are fixed to the outer side surfaces of the bushes **41** mounted on both ends of the outer vessel **22** by use of screws, respectively. The side surfaces of the outer bushes **43** are in contact with both end surfaces of the transparent cylinder **24**, to support the heating lamp **25** by the inner circumferential surfaces thereof.

There exists a sufficient gap between the transparent cylinder **24** and the lamp **25**, so that the transparent cylinder **24** will not be heated to a locally high temperature by the conductive heat from the lamp **25**.

The inlet port **20***a* of the working fluid and the inlet port **22***a* of the cooling liquid are arranged on both opposite ends of the device. Therefore, the working fluid and the cooling liquid flow in mutually opposite directions. In this case, generally the cooling efficiency is excellent, as compared with the case that the working fluid and the cooling liquid flow in the same direction.

As shown by two triangular symbol marks in FIG. **11**, inner fins **44***a* and outer fins **44***b* are fixed to all over the surfaces of both the inner and outer circumferential surfaces of the inner vessel **20**. A slight gap is formed between the ends of the inner fins **44***a* and the transparent cylinder **24** and between the ends of the outer fins **44***b* and the outer vessel **22**, respectively, for the reason as already explained.

As these fines **44***a* and **44***b*, various types as shown in FIGS. **12**(A) to **12**(G) can be adopted. FIG. **12**(A) shows the fines manufactured by bending a thin plate into a corrugated

shape rectangular in cross section. FIG. 12(B) shows the fines manufactured by bending a thin plate into a corrugated shape rectangular in cross section. FIG. 12(C) shows the fines manufactured by bending a thin plate into a corrugated shape ridged in cross section and further undulating the ridged portions. FIG. 12(D) shows the fines manufactured by bending a plurality of narrow thin plates into a corrugated shape rectangular in cross section and further arranging them as their corrugated portions are shifted alternately with each other. FIG. 12(E) shows the fines manufactured by bending a thin plate into a corrugated shape in cross section and further forming a plurality of fine recessed or projected portions on the surface thereof. FIG. 12(F) shows the fines manufactured by bending a thin plate into a corrugated shape rectangular in cross section and further forming louver-shaped cutout portions on the surface thereof. FIG. 12(G) shows the fines of a number of pins. In FIGS. 12(A) to 12(G), each arrow shows a direction parallel to the central axis of the inner vessel **20**; that is, a flow direction of the fluid or the cooling liquid. The arrangements of the fines with the specific relations to the flow directions as shown in these drawings allow the fluid or the cooling liquid flow smoothly without being blocked by the fines.

The inner fines **44***a* and the outer fins **44***b* are arranged dispersively all over the inner space **21** and the outer space **23** at a substantially uniform density, respectively, so that these fines **44***a* and **44***b* act on the fluid and the cooling liquid uniformly all over the places within the inner and outer spaces **21** and **23**, respectively. Therefore, the fluid can be heated and cooled by these fines effectively without producing any temperature non-uniformity. From this point of view, it is preferable that the arrangement density of the fins **44***a* or **44***b* is as high as possible, unless the pressure loss of the working fluid or the cooling liquid caused by the fins causes a problem.

Any fins as shown in FIGS. **12**(A) to **12**(G) are suitable for the inner fines **44***a* because the fins themselves absorb infrared rays and receive the radiation heat effectively. In the case that the working fluid has an extremely small light absorbability, the major part of the infrared rays of the lamp are absorbed by the fins to be converted to heat by repeating the following process as: the infrared rays are allowed to be incident upon any places of the fins, absorbed partially, and reflected partially; and the reflected rays are allowed to be incident upon other places of the fins, absorbed and reflected partially, . . . As a result, the fluid can be heated effectively and uniformly.

On the other hand, In the case that the working fluid absorbs light considerably as with the case of water, the pin type fines as shown in FIG. **12**(G) can be adopted with no problem, since the infrared rays can be are transmitted to all over the fluid. However, In this case, if the fines as shown in FIGS. **12**(A) to **12**(F) are used, since the infrared rays are allowed to be incident upon only the fluid passing through the inside of the fins and not upon the fluid passing through the outside of the fins, the heating efficiency might be lowered.

Therefore, with the device using a working fluid having a relatively high light absorbability, it is preferable to adopt the fins of such types that the infrared rays of the lamp can be emitted to all over the fluid as that shown in FIGS. **8** and **9** or that shown in FIG. **12**(G). On the other hand, with the device using only a fluid having an extremely low light absorbability, it is preferable to adopt the fins of any type including those as shown in FIGS. **8** and **9** and FIGS. **12**(A) to **12**(G).

With the corrugated fins as shown in FIGS. **12**(A) to **12**(F), there exists such an advantage that these fins can be manufactured and mounted on the inner vessel relatively easily.

The above described fluid temperature control device according to the present invention can be applied not only to the distributed type multi-temperature control system as shown in FIG. **4**, but also to various type temperature control apparatus such as the centralized type multi-temperature control system as shown in FIG. **1**, the temperature control system for the constant temperature chamber and so on.

FIG. **13** is a circuit diagram showing a temperature control system using the fluid temperature control device **100** according to the present invention.

In FIG. **13**, a cooling liquid supply pipe **52** is connected to a cooling liquid inlet port **22***a* of the fluid temperature control device **100** via an open/close valve **51**, and a cooling liquid outlet pipe **53** is connected to a cooling liquid outlet port **22***b* of the same device. A relief valve **54** is connected to the cooling liquid outlet pipe **13**. Also, an additional relief valve may be connected on the upstream or downstream side of the open/close valve **51** of the cooling liquid supply pipe **52**.

The fluid inlet port **20***a* of the fluid temperature control device **100** is connect to a fluid return pipe **16** for returning the working fluid from an object **55** of the temperature control, and the fluid outlet port **20***b* is connected to a fluid supply pipe **57** for supplying fluid to the object **55**. The object **55** is an installation for which the temperature control is required such as a constant temperature chamber, plasma CVD apparatus chamber and the like. The temperature of the installation **55** is controlled by the working fluid supplied through the fluid supply pipe **57**.

To the fluid return pipe **56** and the fluid supply pipe **57**, open/close valves **58***a* and **58***b* and temperature sensors **59***a* and **59***b* for measuring the temperature of the working fluid flowing through the pipes **56** and **57** are connected, respectively. A deionization instrument **60** for removing ions from the fluid may be connected to the liquid supply pipe **57**. Further, a pump **61** for circulating the working fluid is connected to either of the liquid supply pipe **57** or the liquid return pipe **56**.

In the circuit as shown in FIG. **13**, when the open/close valves **58***a* and **58***b* are opened and the pump **61** is actuated, the working fluid is circulated through the temperature control device **100** and the installation **55**. Two temperatures of the working fluid are detected by the temperature sensors **59***a* and **59***b* at both the inlet port **20***a* and the outlet port **20***b*, respectively. The detected temperatures are transmitted to a controller (not shown). The controller controls the turn-on time or the electric power of the lamp and the flow rate of the cooling liquid so that the temperature of the fluid at the output port **1***b* matches the target temperature.

The above-mentioned embodiments have been explained for facilitating understanding of the gist of the present invention, so that the scope of the present invention is not limited only to the above-mentioned embodiments. That is, the above-mentioned embodiments can be changed, modified or improved into various modes, without departing from the spirit and scope thereof.

What is claimed is:

1. A fluid temperature control device comprising;

a transparent cylinder;

a lamp arranged within said transparent cylinder, for radiating infrared rays;

a cylindrical vessel arranged so as to surround said transparent cylinder and having an inner space between said transparent cylinder and said cylindrical vessel;

a fluid inlet port for passing a fluid into the inner space;

a fluid outlet port for passing the fluid from the inner space; and

inner fins arranged in the inner space for absorbing radiation heat of said infrared rays radiated from said lamp and for transmitting said radiated heat to said fluid flowing in said inner space; and

wherein said inner fins extend radially roughly along a radiation direction of the infrared rays emitted from said lamp.

2. The fluid temperature control device of claim 1, wherein said inner fins are arranged dispersively all over the inner space.

3. The fluid temperature control device in claim 2, wherein said inner fins are arranged dispersively all over the inner space at a substantially uniform density.

4. The fluid temperature control device of claim 1, wherein said inner fins extend roughly along a flow direction of the fluid.

5. The fluid temperature control device of claim 1, wherein ends of said inner fins are separated away from said transparent cylinder.

6. The fluid temperature control device of claim 1, wherein said transparent cylinder is separated away from said lamp.

7. The fluid temperature control device according to claim 1, wherein the inner fins are in contact with an inner circumferential surface of said cylindrical vessel.

8. A fluid temperate control device comprising:

a transparent cylinder;

a lamp arranged within said transparent cylinder, for radiating infrared rays;

a cylindrical vessel arranged so as to surround said transparent cylinder and having a inner space between said transparent cylinder and said cylindrical vessel;

a fluid inlet port for passing a fluid into the inner space;

a fluid outlet port for passing the fluid from the inner space;

inner fins arranged in the inner space for absorbing radiation heat of said infrared rays radiated from said lamp and for transmitting said radiated heat to said fluid flowing in said inner apace:

an outer cylinder arranged so as to surround said cylindrical vessel and having an outer space between said cylindrical vessel and said outer cylinder;

a cooling liquid inlet port for passing a cooling liquid into the outer space; and

a cooling liquid outlet port for passing the cooling liquid from the outer space.

9. The fluid temperature control device of claim 8, further comprising outer fins arranged in the outer space in contact with an outer circumferential surface of said cylindrical vessel.

10. The fluid temperature control device of claim 9, wherein said outer fins are arranged dispersively all over the outer space.

11. The fluid temperature control device of claim 10, wherein said outer fins are arranged dispersively all over the outer space at a substantially uniform density.

12. The fluid temperature control device of claim 9, wherein said outer fins extend roughly along flow direction of the cooling liquid.

13. The fluid temperature control device of claim 9, wherein ends of said outer fins are separated away from said outer cylinder.

14. The fluid temperature control device of claim 9, wherein said outer cylinder is made of a material having a thermal conductivity lower than that of said inner fins and said outer fins.

15. The fluid temperature control device of claim 8, wherein said fluid inlet port and said fluid outlet port, and said cooling liquid inlet port and said cooling liquid outlet port are arranged in such a way that the fluid and the cooling liquid flow in mutually opposite directions.

16. The fluid temperature control device of claim 9, wherein said inner fins and said outer fins are arranged dispersively all over the inner space and the outer space, respectively.

17. The fluid temperature control device according to claim 8, wherein said inner fins are in contact with an inner circumferential surface of said cylindrical vessel.

18. The fluid temperature control device according to claim 8, wherein said inner fins are arranged dispersively all over the inner space.

19. The fluid temperature control device according to claim 17, wherein said inner fin are arranged dispersively all over the inner space at a substantially uniform density.

20. The fluid temperature control device according to claim 18, wherein said inner fins extend radially roughly along a radiation direction of the infrared rays emitted from said lamp.

21. The fluid temperature control device according to claim 8, wherein said inner fins extend roughly along a flow direction of the fluid.

22. The fluid temperature control device according to claim 8, wherein ends of said inner fins are separated away from said transparent cylinder.

23. The fluid temperature control device according to claim 8, wherein said transparent cylinder is separated away from said lamp.

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